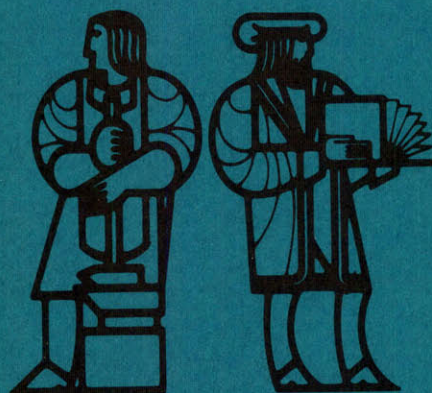


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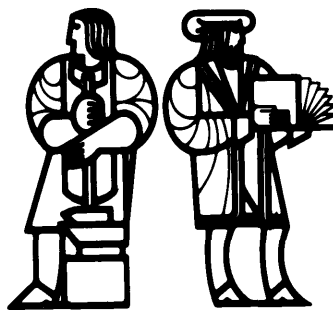
Reports to the President

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1985 - 86

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———Massachusetts Institute of Technology———



## Reports to the President

————— 1985 - 86 —————



Reports for this book were submitted for publication in final, camera-ready form by MIT departments, laboratories, and centers.

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## President

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On April 10, 1861, the Commonwealth of Massachusetts granted a charter to the Massachusetts Institute of Technology for a "Society of Arts, a Museum of Arts, and a School of Industrial Science." This year, MIT celebrated its Quasiquicentennial. The 125 years since its founding have witnessed the growth of an institution of higher learning that is unique, even among the great research universities of the world. MIT's special character resides in the way in which a community of senior and junior scholars -- faculty and students -- come together in a spirit of high mutual regard and uncommon zeal for inventing the future. For throughout our history, we have been involved not only with the discovery of new knowledge, the framing of new ideas and new techniques, but with the education of generation after generation of students in a manner that makes them partners in the process of discovery. Indeed, the idea for a "new education" as envisioned by William Barton Rogers -- an education in which the lamp of learning would rest on a foundation of arts and sciences, and in which "learning by doing" would be a cardinal element -- has created an ethos with few boundaries between the generations, between the disciplines, between the present and the future.

This ethos, this spirit, is kept fresh by the partnerships formed with the students who are drawn to MIT each year. For in so many ways it is the students who provide us with the capacity -- and the imperative -- for continuous self-renewal, comprising as they do a fountain of youth that keeps this place young and vigorous and committed to the idea of a future different from and far better than that which we have known.

This influence is so important that one of our highest priorities must always be the quality of the students who come here to study. The Institute has been blessed with students who are essentially without peer in their intellectual capacity, their commitment to personal achievement, and their motivation for lives of meaning and service. These young men and women draw, inspire, and fulfill the exceptional faculty who shape the educational and research programs of MIT. As one senior member of the faculty said at an orientation meeting for new faculty this fall: "However you teach them, they learn. They are the smartest people in America."

Without students of this caliber, MIT would not be the institution that it is. Strong, motivated students and an extraordinary faculty are the two sides of the coin of excellence. No university can, for very long, have one without the other, and our future depends critically on our ability to attract the best students and provide for them educational programs of lasting value and relevance in a setting that encourages growth and personal development.

\* \* \*

What are the issues most critical to our being able to draw the best students to MIT and provide the best possible education for them? And how would we define the best students and the best education for these times? This report will discuss these concerns and preview the steps we are taking to define a new academic program for undergraduates -- one that will provide each student with the attitudes, habits of mind, and approaches to learning that will assure a lifetime of technical competence, social contribution, and personal fulfillment.

Our students tell us that they are attracted to MIT principally by our reputation for vigorous, high-quality academic programs in which they will have opportunities for substantial intellectual contact with the faculty. At both the undergraduate and graduate levels we have many more qualified applicants for admissions than can be accepted. Consequently, the admissions process focuses not on differentiating the qualified from the unqualified, but on selecting a subset of students from a larger group of applicants, all of whom are qualified to pursue studies here.

The nature of the undergraduate admissions process is such that we have the opportunity to offer admission to a group of young men and women who encompass a wide range of interests and talents and who come from many kinds of social and cultural backgrounds. Our success in enrolling a class that embraces such intellectual and cultural richness is vital to the quality of education that we offer, both inside and outside the classroom. As I have said before, it is our responsibility to help students understand the many ways of seeing and understanding the world, so that they have full access to its opportunities, delights, and challenges. The culture created by the students, as well as the faculty, is a powerful determinant of how successful we are in meeting that responsibility.

An example of student influence on the educational climate is the effect of students' choice of major fields of study. As I have noted in previous reports, the last several years have seen a



steady increase in students selecting a major in engineering, particularly in electrical engineering and computer science. This concentration of undergraduates in a single department and a single school creates severe difficulties for the school and for the Institute. For faculty in the department of Electrical Engineering and Computer Science, the burden of subject supervision, teaching, and advising and thesis supervision is numbing. The load mitigates against the preservation of a reasonable balance of effort involving undergraduate education, graduate education, and research. It also squeezes out the energy and time needed for intellectual self-renewal, curriculum development, and important new initiatives, such as the development of a program of lifelong cooperative education that would serve the needs of many practicing engineers. For several other departments, smaller numbers of undergraduate majors make the provision of a significant undergraduate program difficult and expensive, and are demoralizing for faculty and students alike. For the Institute as a whole, this concentration of interests in a few fields places an unspoken but powerful value on certain fields at the expense of others.

We have acted on this matter in a number of ways, beginning with consideration of the admissions process itself. This past year, the new Director of Admissions and his staff, working under the aegis of the faculty Committee on Undergraduate Admissions and Financial Aid, examined the criteria and the process for recruiting and selecting new students. Their review resulted in the adoption of an enhanced program to inform students about the range of opportunities for study at MIT, which led to an increase in applications, particularly from women. The Director of Admissions reports that the Class of 1990 displays a broader range of academic interests and, as always, comprises students who shine both inside and outside of the classroom. Over 95 percent of those who submitted class standings ranked in the top tenth of their high school classes, and 290 were valedictorians. Out of the freshman class of nearly 1,000, more than 180 had been class officers, nearly 400 had participated in varsity sports, and over 450 had held offices in school organizations. These students, of whom 38 percent are women and 10 percent are underrepresented minorities, came from throughout the country and around the world, bringing with them a richness of cultural background that is an education in itself for their peers.

The Admissions Office, working with the Admissions Committee, has also developed a modified selection procedure aimed at better identifying those students with the traditional strengths we have come to expect and the broader range of interests we seek. The new procedure, which will be inaugurated in the coming year, gives more attention to grades and the quality of a student's academic program as distinct from standardized testing, and seeks to better evaluate such qualities as love of learning, unusual brilliance, creativity, and leadership.

The diversity of students in this class, and among potential applicants, suggests that we will be able to admit classes that embody a broader range of academic and career interests. Our objective should be to create a better match between our students and the range of interests and talents found in our faculty. If we succeed, I believe we will be even more successful in creating a community of scholars, an intellectual and social environment, that is second to none.

\* \* \*

A major factor in our ability to enroll the most desirable students has to do with the cost of an MIT education. As a science- and engineering-based university, our operating costs are high, and we must look to tuition to help meet those costs. It is not surprising that our tuition is among the highest in the nation. For several decades we have admitted undergraduate students on the basis of intellectual, not financial, capacity -- and have provided financial assistance to those who are not able to meet the total cost of attending MIT. Our financial aid packages consist of scholarships and loans, and include the expectation that students will contribute earnings from employment during the summer. We also expect students to help meet their need through loans and/or part-time jobs during the academic year. This latter expectation is generally referred to as the "self-help" requirement.

The income from MIT's permanent endowment for scholarships provides only a fraction of the amount needed for undergraduate aid. During the 1970s and the early years of this decade, an inflationary economy caused costs at MIT and at other similar private universities to increase very rapidly. In spite of these cost increases, we have been able to maintain our policy of providing financial aid to all needy students, primarily by drawing on annual (unrestricted) funds to supplement the internal and external sources of financial aid available to our students. Between 1975 and 1985, this supplemental funding grew fourteen-fold, even though we were substantially increasing our expectations for self-help at the same time. While our use of unrestricted funds to support the financial aid program has remained relatively constant for the past few years, we have achieved this state of precarious equilibrium in large part because of a slowdown in the inflation rate and by continuing to set very high self-help requirements. This year, we were able to hold the self-help expectation at the same level as last year, but at \$4,900, it is the highest in the nation, and is about \$1,000

per year greater than the average level at those private universities with which we compete for the strongest applicants.

During the past several years, the Federal aid programs upon which we depend so heavily have faced strong and recurrent efforts by the administration to shrink or eliminate them. Our ability to continue providing aid to all students with financial need will be threatened if Federal programs of student financial aid are further truncated or if there is a marked increase in the inflation rate. This is a very serious issue, for the nature of our financial aid policy has a great deal to do with the quality of students we can attract and with the quality of their educational experience while at MIT. As the Task Force on Undergraduate Financial Aid Policy noted in its report last year:

"For approximately one half of the undergraduate student body, MIT's financial aid policy is a crucial element in the implicit contract between them and the Institute. This policy directly affects the choice students have in selecting a college, the costs which they and their families will incur, and the level of indebtedness they will have after graduation. It indirectly affects the intellectual, economic, and racial diversity of each undergraduate class, the sense of pressure, and the degree of competition among students. It can exacerbate concerns on the part of students for financial stability. It can, and currently does, give students both the opportunity and the responsibility to choose their personal standard of living and the best balance between their academic work load and a term-time job. And, in a time of economic stringency, it can affect the choice of an academic major, especially when that choice is seen by the student as a vocational as well as an intellectual one."

Any departure from our current policy of admitting students on the basis of merit, without regard to need, is likely to impair seriously our capacity to enroll undergraduate classes of the academic quality and human diversity we have enjoyed in the past, classes that contribute so greatly to the intellectual and social vibrancy of this community.

Preservation of these policies requires, quite simply, that we have more funds available for undergraduate financial aid. MIT's scholarship endowment presently stands at about \$113 million. An addition of \$50 million to this endowment would greatly enhance our ability to meet fully the urgent requirements for scholarships; larger additions would obviously provide some cushion against future diminishment of Federal aid programs and some relief from pressures to increase the self-help level.

The situation with respect to financial assistance for graduate students is different in detail but similar in terms of its influence on our ability to continue to attract and enroll the most able students. For the most part, graduate students are independent of their parents -- indeed, many are married with family responsibilities -- and aid is awarded by MIT as well as outside agencies primarily on the basis of merit. Most graduate students in the Schools of Engineering and Science are supported as teaching assistants or with sponsored research funds as research assistants. But most graduate students in the Schools of Architecture and Planning, Humanities and Social Science, and Management are unable to find such forms of support because the volume of sponsored research activity in those Schools is relatively small. Many of these students rely on part-time employment at the Institute or elsewhere, a fortunate few have partial or full fellowship support, and a significant number find concerns about money for tuition and living costs a constant worry and a significant distraction.

Stringency of resources for graduate student aid has the same deleterious consequences for the quality of the student body as that previously discussed for undergraduates. The ablest students -- those who show the greatest promise and potential -- will always have several opportunities for graduate study at first-class universities. For many of them, the availability of support becomes a major, often determinative, factor in the choices they make.

In a recent review of academic funding priorities, the deans of each of the five Schools ranked additional endowment for scholarships and fellowships as the most important issue. Even in those Schools where support for teaching and research assistants is common, fellowship support during a student's first year -- when he or she can sort out interests and identify specific fields of study for thesis work -- is a great advantage in terms of drawing the most talented and creative students to MIT.

I know that some observers of the academic scene view funds for student aid as discretionary in nature, perhaps even as a luxury. It is clear to me, however, as it is to most of my colleagues in the faculty and administration, that in a world where first-class, publicly supported universities offer education at a lower price, and where the strongest students will always have a choice of



where to study, adequate funds for financial assistance to students, both undergraduate and graduate, are essential if we are to continue to attract students of such remarkable -- some would say stunning -- ability and potential. It would serve such students poorly if they were to make their college choices primarily on financial rather than intellectual grounds.

I referred earlier to the powerful attraction MIT has for students who seek a real partnership with faculty, and of the need to create an even richer intellectual and social environment for this community of scholars. We are already in the forefront on many dimensions. At the undergraduate level, the Undergraduate Research Opportunities Program has been exceptionally successful in this regard. This year, we are developing additional programs that will further enhance the communion between generations, cultures, and fields that enriches a student's education.

Many of these initiatives are being developed as a result of a significant organizational change in the academic administration -- a change that reinforces the role of education and the importance of educational reform in this institution. One of the first acts taken by Professor John M. Deutch as Provost was to create two new positions: Associate Provost for Educational Programs and Policy, held by Professor Samuel J. Keyser, and Dean for Undergraduate Education, held by Professor Margaret L. A. MacVicar. Professor Keyser heads a team of deans which includes, in addition to Professor MacVicar, Professor Frank E. Perkins, Dean of the Graduate School, and Dr. Shirley M. McBay, Dean for Student Affairs.

The creation of a new academic organization devoted to educational issues both inside and outside the classroom has already borne fruit. The following examples are but headlines of activities that range from freshman orientation and first-year programs to graduate student concerns:

- Changes in Residence/Orientation week. In order to introduce new students more effectively into the academic and social life of MIT, a number of changes were made in this year's R/O week. These included providing more time for students to explore academic options; increased involvement of faculty and associate advisors throughout the week; an emphasis on the diversity of MIT, with enhanced orientation programs for women and minorities; and efforts to make residence selection a less hectic and intense focus of the week. We need to do more work in these directions.
- New initiatives to improve freshman advising and strengthen the informal intellectual contact between freshmen and faculty members. These include experiments in having some advisors teach freshman seminars to their advisees; having some advisees and associate advisors grouped in the same house, with advising done in the dormitory setting; and offering some faculty-led undergraduate seminars in the living groups. These experiments are designed to result in improved advising, early exposure of freshmen to the intellectual style of MIT, increased faculty involvement in living groups, better faculty understanding of the freshman year, and a stronger associate advisor program.
- Linking of mathematics and physics sections in the freshman year. The content and pace of the basic freshman subjects in calculus and physics are being coordinated, with the same group of students attending the same physics and mathematics sections, thus fostering intellectual and social cohorts within the academic program. This arrangement also affords an opportunity to better deal with the wide spectrum of mathematics backgrounds among entering students.
- The Institute Colloquium. Outside the classroom, the Institute Colloquium is a new activity which brings students, faculty, and staff together to discuss major issues of concern to the broader community. The plenary sessions, with speakers from outside as well as inside MIT, are followed by discussions in the living groups and led by faculty members. Last year, Institute Colloquia were held on the crisis in South Africa, the AIDS epidemic, and economic competition with Japan. The fall Colloquium, cosponsored with the Corporation Joint Advisory Committee, is being planned on recent developments and prospects in South Africa -- a subject of continuing concern for members of this community.
- A new focus of concern on the quality of the social and academic experience for minority students at MIT. The Office of Minority Education, under its new director, Dr. Joyce Gibson, and in its new home in the Office of the Dean for Student Affairs, is developing its activities in close cooperation with academic departments in supporting minority students through a wide variety of programs. The OME will also be the center for continuing studies relating to the education of minorities at MIT.

In a coordinated effort to attract more minority students to MIT and to support their success, the Offices of Admissions, Financial Aid, Career Services, and Minority Education have created a program for outstanding minority students entitled Pathway to the Future. The Program con-

sists of four parts. The Practical Experience Program, a new service developed by the Career Services Office, is helping students find substantive summer jobs with companies and government agencies in such fields as natural sciences, business, planning, and banking. Other parts of the Pathway Program are the Second Summer Program, which places freshmen in design or research departments in engineering organizations; Project Interphase, which offers first-year students a summer introduction to MIT in advance of the freshman year; and special consideration for families of minority students who need financial aid.

In addition to these programs already in place is a two-year study by a large group of faculty and staff, convened by Dean McBay, which will culminate this fall with reports on the racial climate on campus, financial aid considerations, and other special efforts needed to assure the success of minority students at MIT. I hope to report significant progress and renewed initiatives on this front next year at this time.

- Enhanced attention to graduate student concerns. The inclusion of the Dean of the Graduate School as part of the team headed by the Associate Provost for Educational Programs and Policy has resulted in greater participation by the Graduate School in the planning of educational policy, particularly where issues of graduate education, undergraduate education, and the quality of student life come together. One such issue has to do with the declining number of minority scientists in this country and the need bring more minority undergraduates into graduate programs in the sciences. This year the Graduate School, together with the School of Science and the Provost's Office, launched a new program for minority undergraduates interested in scientific careers. The objective of the program is to give students experience in scientific research in a university setting, with the hope that they will eventually pursue doctoral degrees in science. This past summer, the MIT Minority Summer Science Research Program brought eight minority students to campus for 10 weeks to work with faculty, graduate students, and postdoctoral fellows in research laboratories in the School of Science. Plans call for an expansion of this pilot program to 30 students next summer.

Another set of issues relates to the steady, though unplanned, growth in graduate student enrollments, which now surpass undergraduate enrollments. This issue has raised major policy questions having to do with the impact on the quality of life for all students, the desired relative sizes of the two groups, the effects on faculty research activities, and the impacts and opportunities for controlling the size of the graduate student body -- questions that will continue on our agenda in the coming year.

Related to the issue of graduate enrollment is graduate student housing, which falls far short of meeting the need. Not only does the lack of housing weaken the quality of life for graduate students, it is beginning to have its effect on our efforts to enroll the strongest graduate students as well. As a result, we are making graduate student housing one of our highest priorities for new funding.

These are examples of the renewed interest on the part of the faculty and administration in creating an intellectual and campus environment that enhances the education of students at every level and welcomes, values, and learns from the extraordinary mix of intellectual, social, and cultural perspectives among us.

Of all the new initiatives, however, none is more significant than the current assessment and reform of undergraduate education at MIT. The Institute is now engaged in the most intensive review of its undergraduate academic program in 25 years. Sparked by a sense that there is a need in undergraduate education for more integration of perspectives and expertise among fields and a need for a greater common view of an undergraduate program drawing on the special strengths of MIT, faculty in the various Schools have formed into committees to study various aspects of our programs -- including undergraduate education in engineering; the core requirements in science and the humanities, arts, and social sciences; and the overall structure and purpose of the undergraduate program itself.

These reviews are being conducted under the auspices of the Deans of the Schools and the Dean for Undergraduate Education. The newly formed faculty Committee on the Undergraduate Program is taking an important role in bringing together the many threads from these various committees into a tentative, interrelated framework for a new set of General Institute Requirements, which would constitute the core of the academic program for every undergraduate at MIT.

During the coming year, the reviews and recommendations of these faculty committees will be under discussion in the faculty at large, in order to develop a broadly shared common conception with regard to the assumptions and purpose of our undergraduate program. The reports and discussions to

date indicate a widespread interest among the faculty in educational reform, and I am indebted to the many individuals on the faculty who are taking part in this major undertaking.

This intensive review of the structure and content of undergraduate education at MIT is motivated by several considerations:

- The world in which our students will live and work is changing at ever-increasing rates. This is particularly so in science-based activities and in those fields that generate and are driven by new technology. We have a particular responsibility to insure that the education we provide has value and relevance over a lifetime of professional activity, and that it prepares our graduates for the necessity of continual learning and mastery of ideas not yet conceived. Our most important educational task is to prepare students for independent learning and a lifetime of intellectual self-renewal.
- There is a widely shared, but by no means unanimous, sense that the quality of the MIT educational experience for many students is impaired by the intensity or pace of our programs. This is a community of highly motivated and energetic high-achievers. Many would subscribe to Mae West's view that "too much of a good thing is wonderful." If a normal load is five subjects, why not take six or seven since the rules of the Institute permit it? What can be the harm in taking on one more committee assignment in addition to that peer-review panel for the National Academy of Sciences? After all, the subject is important, one is interested in it, and one can always squeeze out a bit more time from teaching, research supervision and participation, consulting, and that manuscript which is going too slowly. I am convinced that the self-reinforcing habits of overextension, which are part of the lives of so many members of this community -- students, faculty, staff, and administrators alike -- exact a toll on creativity, collegiality, and the quality of our community life, and I believe that an intentional, modest reduction in pace, in intensity, with more time for contemplation and reflection would be desirable. If this is to occur, we need to understand the ways in which the structure of the curriculum and the long-standing tradition of absolute freedom of choice in registration contribute to or reinforce this behavior.
- At MIT and elsewhere, the structure of undergraduate engineering education -- always a compromise with respect to the time allocated to three competing and essential elements: mathematics, science, and engineering fundamentals; humanities, arts, and social sciences; engineering applications, including design experience -- is widely thought to be overconstrained. It may be time to recognize that an undergraduate degree at MIT may provide the best foundation for professional engineering studies, but that proper professional qualifications may well require additional educational and learning experiences and that continued learning is an essential element in the career of an engineer.
- Many members of the faculty and many undergraduate students are dissatisfied with the present structure of the Institute Requirement in the humanities, arts, and social sciences. There is general agreement on the proposition that all MIT undergraduates should receive a broad foundation in the humanities, arts, and social sciences; that they should develop their capacities in areas of learning that are contextual and interpretive and should learn to make reasoned judgments employing non-quantitative modes of analysis; and that they should develop their abilities to express their thoughts and feelings through writing and speaking. But there is also a clear sense that the present Institute requirements do not achieve these purposes. Under the current HASS requirement, there is no assurance of adequate breadth in the individual student's programs, there are no common elements in those programs, and many of the subjects that can be used to satisfy the present requirements are highly quantitative or are designed primarily to teach professionally useful skills.

We at the Institute have both a heavy responsibility and a great opportunity with respect to undergraduate education. That responsibility is associated with the fact that the students who come to us represent, in terms of past achievement, future promise, and innate abilities, an extraordinary selection of young men and women. Most will lead lives of personal and social significance and will have careers that make a difference. Many will achieve greatness in what they undertake, and many will grow into positions of leadership in the professions, in the world of industry and commerce, and in government. We must make the best possible use of the few years these young people are with us, for they represent an extraordinary human resource -- one that matters to this nation and to the world.

We have a great opportunity -- not only because these young people are so very able but also because in its programs and, most importantly, in its faculty this special place embodies a range of fields

and activities of particular relevance to the world of the 21st century. Increasingly, the issues and choices facing societies, developed and developing, have crucial scientific or technological components, and wise, humane choices will require scientific literacy among leaders and shapers of opinion. One would hope for greater scientific literacy among citizens at large; regrettably, public secondary education seems to be moving in the opposite direction. At the same time, the evident impact of science and technology on public affairs and human well-being requires that those who shape or influence these developments appreciate the diversity and complexity of societies and human values and have an ability to understand and respect the economic, political, social, and environmental issues associated with the technical developments and applications of science.

The Institute embodies these skills and intellectual disciplines, and we have the capacity to educate in ways that nurture and develop these multiple competencies, even as our students have the capacity to appreciate and master these complementary perspectives. One of the greatest resources we can place in the service of this mission is our tradition of faculty and students working and learning together -- in a spirit that encourages the best each has to offer and that reflects a degree of collegiality that is remarkable for a research university. In these respects, MIT is singular. It is a singularity that gives me reason to be very hopeful about the ways in which we will discharge the educational responsibility we hold, and meet the educational opportunities presented to us.

PAUL E. GRAY  
September 1986



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## In Special Recognition

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The special character of MIT is seen each year in the achievements and honors of its faculty. While it is not possible to take note of every such distinction, there are some highlights which deserve mention.

In the early spring the National Academy of Engineering elected five members of the MIT Faculty. New MIT members are: H. Kent Bowen, Professor of Materials Science and Engineering and Director of the Manufacturing and Processing Systems Program; Chiang C. Mei, Professor of Civil Engineering; Joel Moses, Professor and Head of Electrical Engineering and Computer Science; Kenneth N. Stevens, Professor of Electrical Engineering and Computer Science; and Daniel I.C. Wang, Professor of Chemical Engineering and Applied Biological Sciences, and Director of the Biotechnology Center.

During the spring four members of the faculty were elected members of the National Academy of Science. Those new MIT members are: Emilio Bizzi, Eugene McDermott Professor in Brain Sciences and Human Behavior and Director of the Whitaker College of Health Sciences, Technology and Management; Daniel Kleppner, Professor of Physics; Sheldon Penman, Professor of Biology; and Susumu Tonegawa, Professor of Biology in the Center for Cancer Research.

Seven members of the MIT faculty were amongst those elected as Fellows of the American Academy of Arts and Sciences at its May meeting. New MIT members are: Daniel Z. Freedman, Professor of Applied Mathematics; Daniel Kleppner, Professor of Physics; Stephen J. Lippard, Professor of Chemistry; Richard B. Melrose, Professor of Mathematics; Robert C. Merton, Professor of Management; Peter Temin, Professor of Economics; and Martin L. Weitzman, Professor of Economics.

In October 1985 Professor Franco Modigliani was awarded the 1985 Alfred Nobel Memorial Prize in Economics. The award was given for his pioneering analyses of how individual savings patterns and capital markets influence the overall course of national economies. His "life-cycle" theory, which maintains that people routinely vary their saving during their lifetimes, has been adopted by economists to study everything from retirement to taxes.

David Epstein, Professor of Music and Music Director of the MIT Symphony Orchestra, was named a recipient of the Senior US Scientist Award of the Alexander von Humboldt Foundation for his research into questions of time process and time structure in music, which has amalgamated music theory with aspects of neurophysiological timing mechanisms that seem to control timing in music making.

In the spring, Herman Feshbach, Institute Professor and Professor of Physics, received the National Medal of Science for his distinguished contributions to science as a leader in physics education.

Bruce Mazlish, Professor of History, was awarded The Toynbee Prize this spring for his theories exploring the impact of psychology on history and public policy. A major international award, The Toynbee Prize is awarded biannually to an outstanding scholar for work enriching the social sciences.

The 1985 Enrico Fermi Award, presented by the United States Department of Energy, was given this year to Norman C. Rasmussen, Professor of Nuclear Engineering, in recognition of his pioneering work in developing probabilistic risk assessment methods for analyzing reactor safety.

Susumu Tonegawa of the Center for Cancer Research and the Department of Biology received the ninth annual Bristol-Myers Award for Distinguished Achievement in Cancer Research for his work in deciphering the genetic basis of how the immune system works.

In May, Sheila E. Widnall, Professor of Aeronautics and Astronautics, became president-elect of the American Association for the Advancement of Science, the world's leading general scientific organization.

The National Academy of Engineering announced in July 1985 that Jerome B. Wiesner, President Emeritus and Institute Professor, was the recipient of the Arthur M. Bueche Award for his personal leadership at the highest levels in the area of high-performance communication systems, science policy in the Federal government, and scientific and engineering education.

Within the Institute, Mildred S. Dresselhaus, Abby Rockefeller Mauze Professor of Electrical Engineering and Physics, was named an Institute Professor. The title of Institute Professor is an

honor bestowed by the faculty on a colleague for distinguished accomplishments in scholarly, educational, service, and leadership pursuits. Professor Dresselhaus has focused her scholarly attention on electronic, optical, and magnetooptical properties of semiconductors and semimetals. She has earned a national reputation as an educator and leader in developing wider opportunities for women in science and engineering.

Later in the spring, Professor Dresselhaus was selected as the 1986-87 recipient of the James R. Killian, Jr. Faculty Achievement Award. The Killian Award, established in 1971 as a tribute to MIT's tenth president, recognizes extraordinary professional accomplishments and service. The committee's citation notes that Professor Dresselhaus "through her professional and her personal lives, gives distinction to MIT, but also human coherence and purpose."

In May, Jeffrey H. Lang, Associate Professor of Electrical Engineering and Computer Science, was named the 1986 recipient of the Harold E. Edgerton Faculty Achievement Award. This Award recognizes young faculty members for outstanding achievements in research, scholarship, and teaching. The committee's citation notes that Professor Lang "has demonstrated a commitment to excelling on each of these dimensions....He brings to his work insight that combines the discipline of microprocessors, power electronics, field theory, control, and other areas." It further states that Professor Lang's "skill and dedication as a teacher is well known among faculty and students."

\* \* \*

This past year, several key leadership roles at the Institute changed, and those transitions were occasion for special recognition.

Several changes in senior posts in the academic administration were announced this past year. In September, Professor Jack L. Kerrebrock, the Richard Cockburn Maclaurin Professor in Aeronautics and Astronautics and Head of the Department of Aeronautics and Astronautics, was named Associate Dean of the School of Engineering. New department or program heads appointed or announced during the past year are: Richard S. Eckaus, Head of the Department of Economics; Shaoul Ezekiel, Director of the Center for Advanced Engineering Study; Kenneth Keniston, Director of the Program in Science, Technology, and Society; Richard J. Kitz, Codirector of the Harvard-MIT Division of Health Sciences and Technology; Claire Kramsch, Section Head of Foreign Languages and Literature; Tunney F. Lee, Head of the Department of Urban Studies and Planning; Robert W. Mann, Director of Bioengineering Programs at the Whitaker College of Health Sciences, Technology and Management; James McKellar, Director of the Center for Real Estate Development; Joseph M. Sussman, Director of the Center for Transportation Studies; and Harry L. Tuller, Director of the Crystal Physics and Optical Electronics Laboratory.

Several changes in the Institute's central administration also were announced during the year. In the spring, Professor James D. Bruce, Director of Information Systems, was appointed to the new position of Vice President for Information Systems, effective July 1. As vice president, Professor Bruce will be the senior officer responsible for directing the evolution, integration, and effective use of computing and communications resources throughout MIT.

Mr. Glenn P. Strehle, Treasurer of the MIT Corporation since July 1975, was appointed to succeed Professor Samuel A. Goldblith as Vice President for Resource Development effective March 1, 1986. He will continue to be treasurer of the Corporation and his new title will be Vice President and Treasurer. Professor Goldblith, who served as Vice President for Resource Development for the past seven years, will return to teaching and research as Professor of Food Science in the Department of Applied Biological Sciences and will also remain part-time as Senior Advisor to the President for Resource Development.

At the October 4, 1985 meeting of the Corporation, Mr. Constantine B. Simonides was elected Secretary and ex officio member of the MIT Corporation. He will continue his current duties as Vice President in the Office of the President.

Other appointments include the appointment in the spring of Mr. Kenneth D. Campbell as Director of the MIT News Office, Dr. Allan S. Bufferd as Deputy Treasurer and Director of Investments, and Dr. Joyce T. Gibson, as Director of the Office of Minority Education.

In this section of my report I would like to take special notice of the fact that in the last two years 30 members of underrepresented minority groups, 26 of them black, joined the Institute's administrative staff. In a total staff of 900 this addition represents more than 30 percent of the minority component, which is under 100. I wish I could have reported similar progress in the recruitment of faculty members.

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The Institute was saddened this year by the deaths of several longtime friends and colleagues. We miss them and are grateful for their contributions to this community.

John B. Babcock, professor of railway engineering emeritus in the Department of Civil Engineering, died in February 1986 at the age of 96. A 1910 graduate of MIT, he served on the faculty from 1916 until his retirement in 1954.

In April 1986, Lloyd D. Brace, former president and chairman of the First National Bank of Boston and a Life Member Emeritus of the MIT Corporation, died at age 83. As a member of the MIT Corporation, Mr. Brace played a prominent role in the planning and financing of capital projects for the Institute, and had a long and distinguished record of visiting committee service.

Douglass V. Brown, Jr., a renowned arbitrator and a professor emeritus in the Sloan School of Management, died at the age of 82 in March 1986. His service to the Institute spanned a period of 36 years, during which time his expertise in the field of industrial relations and arbitrations influenced generations of students.

In March 1986, Secor D. Browne, a former faculty member who was chairman of the Civil Aeronautics Board from 1969-1973, died at age 69. His varied interests enabled him to hold joint appointments at MIT in the Department of Aeronautics and Astronautics and the Department of Modern Languages.

Martin J. Buerger, a retired professor renowned for his laboratory and pioneering work in the application of X-ray crystallography, died at age 82 in February 1986. In 1920 he enrolled as an undergraduate at MIT and then served for 55 years at the Institute as professor of mineralogy and crystallography. In 1944 he was appointed Institute Professor, a rank of special distinction conferred by fellow faculty members.

Donald F. Carpenter, former general manager of the Film Department of E.I. du Pont de Nemours and Company and senior Life Member Emeritus of the MIT Corporation, died in September 1985 at the age of 86. A member of the class of 1922, his association with MIT spanned more than six decades, during which time he served as a trusted advisor to five MIT presidents and four of the Corporation's chairmen.

In January 1986, Morton Finston, a retired professor of aeronautics and astronautics, died at the age of 66. He served on the MIT faculty for 33 years until his retirement in 1984. His fundamental work was in aerodynamics and heat transfer.

Billy E. Goetz, who served as a professor of management at the Sloan School from 1954 until his retirement in 1969, died in September 1985 at the age of 81. At Sloan, Professor Goetz specialized in production management and managerial accounting with a focus on definitions, characteristics, and sources of information for managerial planning and control.

In January 1986, August L. Hesselschwerdt Jr., emeritus professor of mechanical engineering, died at the age of 75. A graduate of MIT, he returned to the Institute in 1942 as a member of the faculty, remaining until his retirement in 1975.

Harold R. Isaacs, professor emeritus of political science and a noted writer on Asian, African, and American affairs, died in July of 1986. He started his career as a writer and journalist, establishing his literary reputation at age 28 with the publication of his study of the Chinese Revolution of 1925-27. Professor Isaacs came to MIT as a research associate in 1953 and served as professor of political science from 1965 until his retirement in 1976.

Thomas B. King, professor in the Department of Materials Science and Engineering, died at the age of 62 in November 1985. Professor King joined the MIT faculty in 1953 and was widely known for his dedicated teaching and concern about the undergraduate educational experience. He was a leading authority in chemical metallurgy and chemical kinetics.

Edwin Kuh, a professor of economics and finance and a pioneering figure in econometric studies, died in June 1986 at the age of 61. Holding joint appointments in the Sloan School of Management and the Department of Economics, he was an authority on econometric models and the measurement of their reliability to forecast such functions as production, savings, investment, business cycles, and unemployment.

Roy Lamson, professor of literature emeritus, died at the age of 78 in May 1986. He was a champion of the arts and humanities at MIT, the creator of Course XXI, and was a founding member of the Council for the Arts at MIT. In addition to his teaching, he was a writer, an historian with an interest in international relations and military affairs, and a talented clarinet player who was a founding member of The Intermission Trio.

Robert A. Lovett, an international financier and Life Member Emeritus of the Corporation, died in May 1986 at the age of 90. Mr. Lovett was associated with Brown Brothers Harriman for more than 60 years and served as a member of the MIT Corporation since 1955.

Philip M. Morse of the Department of Physics died in September 1985 at the age of 82. His interests ranged from underwater acoustics to astrophysics, and he made pioneering and seminal contributions to the science and practice of operations research, the use of computers in research, and the civilian uses of atomic power.

Shatwell Ober, the aeronautics engineer whose pioneering research in wind tunnel design and testing made significant contributions to aviation, died in September 1985 at age 91. A 1916 graduate of MIT, he returned to MIT in 1922 and remained on the faculty until his retirement in 1959.

Fairfield E. Raymond, 89, an MIT alumnus and faculty member, died in November 1985. He taught in the Department of Electronics from 1928 to 1930 and in the Department of Business and Engineering Administration, the forerunner to the Sloan School of Management, from 1930 to 1939.

David J. Rose of the Department of Nuclear Engineering died in October 1985 at the age of 63. He had been a member of the MIT faculty since 1958 and was recognized for a distinguished career as scientist and engineer, technology and policy analyst, and bridge builder between the scientific and theological communities.

John T. Rule II, emeritus professor of Mechanical Engineering, former Dean of Students and head of General Science and General Education, died at age 85 in May 1986. A 1921 graduate of MIT, he served on the faculty from 1936 until his retirement in 1966, including five years as Dean of Students from 1956-1961.

Karl L. Wildes, professor emeritus in the department of Electrical Engineering and Computer Science, died in April 1986 at age 90. He was noted for his work in the applications of mathematical physics to network theory, especially in the transmission and distribution of electrical power, and for his contributions to the development of cooperative education at MIT. More recently, in 1985 he completed with co-author Nilo A. Lindgren a major historical work entitled A Century of Electrical Engineering and Computer Science at MIT, 1882-1982, which was published by the MIT Press.

John J. Wilson, an industrialist who founded several successful companies, a yachtsman who sailed the Atlantic five times, a Life Member of the MIT Corporation, and a prominent Boston-area trustee, died in December 1985 at the age of 78. An MIT graduate, he became an outstanding leader in MIT alumni affairs, serving the Institute in a number of capacities including Secretary of the Corporation.

In July of 1986, Dr. Jerrold R. Zacharias, recognized internationally as a leader in nuclear physics and in educational reform, died at the age of 81. An Institute Professor Emeritus and professor emeritus of physics, Dr. Zacharias was widely known for his investigations of the radio frequency spectra of atoms which led to the first atomic clock. His distinguished service to physics education included the formation of the Physical Science Study Committee (PSSC) in 1956 which developed a new method for teaching physics in high schools.

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## Statistics for the Year

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The following paragraphs report briefly on various aspects of the Institute's activities and operations during 1985-86.

### Registration

In 1985-86 student enrollment was 9,787, compared with 9,626 in 1984-85. This total was comprised of 4,541 undergraduates (compared with 4,536 the previous year), and 5,246 graduate students (compared with 5,090 the previous year). Graduate students who entered MIT last year held degrees from 412 colleges and universities, American and foreign. The international student population\* was 2,249, representing 13 percent of the undergraduate and 31 percent of the graduate population. These students were citizens of 96 countries.

In 1985-86, there were 2,218 women students (1,176 undergraduate and 1,042 graduate) at the Institute, compared with 2,211 (1,157 undergraduate and 1,054 graduate) in 1984-85. In September 1985, 290 first-year women entered MIT, representing 27 percent of the entering class.

In 1985-86, there were 1,241 minority\*\* students (1,047 undergraduate and 194 graduate) at the Institute, compared with 1,189 (1,021 undergraduate and 168 graduate) in 1984-85. The first-year class entering in September 1985 included 285 minority students, comprising 27 percent of the class.

### Degrees Awarded

Degrees awarded by the Institute in 1985-86 included 1,231 bachelor's degrees, 1,059 master's degrees, 54 engineer's degrees, 455 doctoral degrees -- a total of 2,799.

### Student Financial Aid

During the academic year 1985-86 the student financial aid program was again characterized by an increase in the overall need for financial aid and in the aggregate amount of grants made available. There was an increase in the amount of MIT loans awarded. Federally guaranteed loans obtained from commercial sources showed a small decrease.

A total of 2,456 undergraduates who demonstrated the need for assistance (54 percent of the enrollment) received \$15,733,000 in grant aid and \$3,275,000 in loans. The total, \$19,008,000, represents a 6 percent increase in aid compared to last year.

Grant assistance to undergraduates was provided by \$4,440,000 in income from the scholarship endowment, by \$2,129,000 in outside gifts and Federal allocations to MIT for scholarships, and by \$3,484,000 in direct grants from outside sources, including ROTC, to needy students. In addition, \$5,586,000 in scholarships from MIT's unrestricted funds was provided to undergraduates. The special program of scholarship aid to minority group students represented an additional \$94,000 from specially designated funds. An additional 702 students received grants from outside agencies, irrespective of need. The undergraduate scholarship endowment was aided by the addition of \$2,292,000 in new funds which raised the principal of the endowment to \$40,418,000\*\*\*.

Loans totaling \$3,275,000 were made to needy undergraduates -- a 6 percent increase from last year. Of this amount \$823,000 came from the Technology Loan Fund and \$2,452,000 from the National Direct Student Loan Fund. Not included in the foregoing summary is an additional \$5,629,000 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources. This represents a 1.5 percent decrease in the use of these programs over last year.

\*Includes permanent residents.

\*\*Minority students include 295 Blacks (non-Hispanic), 22 Native Americans, 234 Hispanics, and 690 Asian Americans.

\*\*\*Book Value. Market Value as of June 30, 1986 is \$113,400,000.

Graduate students obtained \$1,396,000 from the Technology Loan Fund, \$362,000 of which was loaned to international students and did not qualify for the Federal interest subsidies and guarantees available under the Guaranteed Student Loan Program. In addition, \$120,000 was loaned by MIT under the Guaranteed Student Loan Program. The total, \$1,516,000 represents a 7 percent decrease from last year's level. Graduate students obtained \$3,395,000 from outside sources under the Guaranteed Student Loan Program -- about the same as last year. The total loaned by MIT to both graduate and undergraduate students was \$4,791,000, a 2 percent increase over last year.

### Career Services and Preprofessional Advising

The number of offers reported by students and employers to the Office of Career Services trailed last year's figures in most fields of engineering. The decrease was particularly noticeable in chemical and mechanical engineering. In chemical engineering there were fewer seniors looking for work because fewer sophomores have been choosing chemical engineering, but students in mechanical engineering felt the sting of fewer openings and some were without jobs at graduation. Three fields in which the number of offers was up were aeronautics and astronautics, civil engineering, and computer science. This reflects, perhaps, the rise in defense spending, the current construction boom, and increased dependence on computers in every walk of life.

In all, 395 companies and government agencies recruited through the office and conducted 8,978 interviews. This compares to 431 employers recruiting on campus, and 9,012 interviews in 1984-85. At the bachelor's level, salary offers to MIT students rose sharply in dollar amounts in civil engineering, and rose by more than the inflation rate in mathematics, materials science and engineering, aeronautics and astronautics, computer science, and chemical engineering. Offers trailed the inflation rate in electrical and mechanical engineering. Offers to masters in engineering were generally up by more than the inflation rate. Offers to doctoral candidates were up by more than the inflation rate. Offers to doctoral candidates were up by more than the inflation rate in electrical engineering and materials science, but stayed at last year's dollar figures in chemical and mechanical engineering.

Bucking a national decline in the number of applicants to medical school, MIT fielded 122 candidates in 1985-86 compared with 114 in 1984-85 (also an increase over the previous year). Of the 122, 87 were undergraduates, 10 were graduate students, and 25 were alumni. Preliminary returns indicate that 73 of the undergraduates (84 percent), 8 of the graduate students (80 percent), and 18 of the alumni (72 percent) were accepted.

Twenty-six MIT candidates are known to have applied to law school, among them 18 undergraduates.

### Finances

As reported by the Vice President for Financial Operations and the Treasurer, the total financial operations of the Institute, including sponsored research, amounted to \$790,803,000, an increase of 10 percent over 1984-85. Education and general expenses -- excluding the direct expenses of departmental and interdepartmental research and the Lincoln Laboratory -- amounted to \$331,092,000 during 1985-86, compared to \$299,035,000 in 1984-85. The direct expenses of departmental and interdepartmental sponsored research on campus increased from \$168,311,000 to \$179,648,000; and direct expenses of the Lincoln Laboratory's sponsored research increased from \$249,841,000 to \$280,063,000.

Current revenues used to meet the Institute's operating expenses totaled \$789,184,000, augmented by \$1,619,000 in unrestricted gifts. After meeting these expenses, a surplus of \$1,507,000 in current unrestricted gifts was held at year-end.

The construction program of the Institute continued to make progress in 1985-86, with book value of educational plant facilities increasing from \$306,490,000 to \$321,681,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, students' notes receivable, and amounts due from educational plant, had a book value of \$784,089,000 and a market value of \$1,175,678,000. This compares to book and market values of \$679,820,000 and \$920,658,000 last year.

### Gifts

Gifts, grants, and bequests to MIT from private donors declined by 11 percent in 1985-86 to \$54,783,000, as compared to \$61,714,000 in 1984-85. The Alumni Fund reported gifts of \$11,178,000 for the year, another record.



### Physical Plant and Campus Environment

The arts and media technology building was completed early in the year and officially dedicated in October in honor of Jerome B. and Laya W. Wiesner. Construction of an Experimental Media Facility in unfinished space within the building commenced in late spring and is scheduled for completion early next winter. The fitting out of the Microsystems Technology Laboratory was completed in the spring and most of the laboratories in the facility are now operational.

Major utility, service, and restoration projects completed this year include extension of the central chilled water system to the National Magnet Laboratory on the northwest campus; rehabilitation and modernization of elevators in Buildings 54, 56, and E52; and restoration of the parking garages. The main staircase of the Stratton student center and the Kresge brick plaza were substantially reconstructed.

Again this year, modernization and maintenance of the housing system was a high priority. Over \$1 million was invested in restoration and repairs at Senior House and the East Campus dormitories. In addition, one of our most successful projects with respect to its positive environmental impact, namely landscaping of the area around the East Campus dormitories and Walker Memorial, was also completed.

During the year, MIT and AT&T-Information Systems entered into an agreement to replace MIT's present Centrex and Dormline systems with a 5ESS digital switching or PBX system. As part of this project, a new universal interior wiring system must be installed throughout the Institute. Work on this phase of the project began this year. The 5ESS system is scheduled to be completed and in service by June of 1988. Gateways to campus computer networks have now been installed in 19 different building locations, enabling various computer users throughout the campus to share resources and transfer files. In addition, a number of departmental local area networks were installed during the year.

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## Personnel Changes

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### CORPORATION

#### DEATHS

Lloyd D. Brace  
Life Member, Emeritus

Donald F. Carpenter  
Life Member, Emeritus

Robert A. Lovett  
Life Member, Emeritus

John J. Wilson  
Life Member, Emeritus

#### CHANGES OF APPOINTMENT

Frank R. Milliken  
Life Member, Emeritus

#### ELECTIONS

E. Milton Bevington  
Member

Ernest U. Buckman  
Member

Alex W. Dreyfoos, Jr.  
Member

Joe F. Moore  
Member

DuWayne J. Peterson, Jr.  
Member

Constantine B. Simonides,  
Secretary  
Member

Charles H. Spaulding  
Member

Sarah A. L. Tabler  
Member

Morris Tanenbaum  
Member

#### MEMBER EX-OFFICIO

Joseph G. Gavin, Jr.  
President  
Alumni Association

Harold Raynolds, Jr.  
Commissioner of Education  
Commonwealth of Massachusetts

#### TERMS EXPIRED

Harl P. Aldrich, Jr.  
Member

Elizabeth M. Drake  
Member

Barbara M. Johnston  
Member

George M. Keller  
Member

### FACULTY

#### DEATHS

Thomas B. King  
Department of Materials  
Science and Engineering

Edwin Kuh  
Sloan School of Management

David J. Rose  
Department of Nuclear  
Engineering

#### RETIREMENTS

Sidney S. Alexander  
Sloan School of Management

Warren A. Ambrose  
Department of Mathematics

Eugene Bell  
Department of Biology

Harald A. Enge  
Department of Physics

Nicholas J. Grant  
Department of Materials  
Science and Engineering

Harold J. Hanham  
History Section  
Department of Humanities

Robert I. Hulsizer, Jr.  
Department of Physics

Benjamin Lax  
Department of Physics

Herbert H. Richardson  
School of Engineering

Richard D. Robinson  
Sloan School of Management

Melvin H. Rodman  
Medical Department

Clifford G. Shull  
Department of Physics

Myron Tribus  
School of Engineering

Phyllis A. Wallace  
Sloan School of Management

### FACULTY RESIGNATIONS

#### Professor

Fischer Black  
Professor  
Sloan School of Management

Jerry A. Fodor  
Professor  
Department of Linguistics  
and Philosophy

John R. Ross  
Professor  
Department of Linguistics  
and Philosophy

Erik H. Vanmarcke  
Professor  
Department of Civil

#### Associate Professor

Thomas P. Bligh  
Associate Professor  
Department of Mechanical  
Engineering

Robert V. Kenyon  
Associate Professor  
Department of Aeronautics  
and Astronautics

Terry A. Marsh  
Associate Professor  
Sloan School of Management

Leigh McAlister  
Associate Professor  
Sloan School of Management

Peter Mikhalevsky  
Associate Professor  
Department of Ocean  
Engineering

John D. W. Morecroft  
Associate Professor  
Sloan School of Management

Walter Powell  
Associate Professor  
Sloan School of Management

Ram T. S. Ramakrishnan  
Associate Professor  
Sloan School of Management

Ka Kit Tung  
Associate Professor  
Department of Mathematics

Gordon B. Walker, Jr.  
Associate Professor  
Sloan School of Management

Martha W. Weinberg  
Associate Professor  
Department of Political Science

Scott Weinstein  
Associate Professor  
Department of Linguistics  
and Philosophy

Assistant Professor

David G. Anderson  
Assistant Professor  
Sloan School of Management

John F. Brady  
Assistant Professor  
Department of Chemical  
Engineering

Harvey J. Bryan  
Assistant Professor  
Department of Architecture

John P. Carriero  
Assistant Professor  
Department of Linguistics  
and Philosophy

I-Wei Chen  
Assistant Professor  
Department of Nuclear  
Engineering

Manuel Delgado  
Assistant Professor  
Foreign Languages and  
Literatures Section  
Department of Humanities

Howard Eiland  
Assistant Professor  
Literature Section  
Department of Humanities

William Goldman  
Assistant Professor  
Department of Mathematics

Christopher Guzy  
Assistant Professor  
Department of Chemical  
Engineering

Thereza Imanishi-Kari  
Assistant Professor  
Department of Biology

James L. Powell  
Assistant Professor  
Department of Economics

Robert Dale Sproull  
Assistant Professor  
Department of Chemical  
Engineering

Christopher J. Terman  
Assistant Professor  
Department of Electrical  
Engineering and Computer  
Science

Gunther Uhlmann  
Assistant Professor  
Department of Mathematics

PROMOTIONS

To Professor

Gregory B. Baecher  
Professor  
Department of Civil  
Engineering

Olivier J. Blanchard  
Professor  
Department of Economics

Oral Buyukozturk  
Professor  
Department of Civil  
Engineering

John C. Cox  
Professor  
Sloan School of Management

William M. Deen  
Professor  
Department of Chemical  
Engineering

Martin Diskin  
Professor  
Anthropology and Archaeology  
Program  
Department of Humanities

James L. Elliot  
Professor  
Department of Earth,  
Atmospheric and Planetary  
Sciences

David E. Housman  
Professor  
Department of Biology

Robert S. Langer  
Professor  
Department of Applied  
Biological Sciences

Tunney F. Lee  
Professor  
Department of Urban Studies  
and Planning

Kenneth R. Manning  
Professor  
Writing Program  
Department of Humanities

Travis R. Merritt  
Professor  
Literature Section  
Department of Humanities

R. Alan North  
Professor  
Department of Applied  
Biological Sciences

Daniel N. Osherson  
Professor  
Department of Psychology

Jeffrey H. Shapiro  
Professor  
Department of Electrical  
Engineering and Computer  
Science

Marcus A. Thompson  
Professor  
Music Section  
Department of Humanities

David Thorburn  
Professor  
Literature Section  
Department of Humanities

Donald E. Troxel  
Professor  
Department of Electrical  
Engineering and Computer  
Science

J. Kim Vandiver  
Professor  
Department of Ocean  
Engineering

Barry L. Vercoe  
Professor  
Music Section  
Department of Humanities

To Associate Professor

Katharine G. Abraham  
Associate Professor  
Sloan School of Management

Triantaphyllos R. Akylas  
Associate Professor  
Department of Mechanical  
Engineering

Haruhiko Asada  
Associate Professor  
Department of Mechanical  
Engineering

Bernard Avishai  
Associate Professor  
Writing Program  
Department of Humanities

Max H. Bazerman  
Associate Professor  
Sloan School of Management

Wai K. Cheng  
Associate Professor  
Department of Mechanical  
Engineering

Kathryn J. Crecelius  
Associate Professor  
Foreign Languages and  
Literatures Section  
Department of Humanities

John Dreher  
Associate Professor  
Department of Physics

Kerry A. Emanuel  
Associate Professor  
Department of Earth,  
Atmospheric and Planetary  
Sciences

Leonard P. Guarente  
Associate Professor  
Department of Biology

Joseph H. Haritonidis  
Associate Professor  
Department of Aeronautics  
and Astronautics

John M. Hollerbach  
Associate Professor  
Department of Psychology

Robert V. Kenyon  
Associate Professor  
Department of Aeronautics  
and Astronautics

Philip S. Khoury  
Associate Professor  
History Section  
Department of Humanities

Monty Krieger  
Associate Professor  
Department of Biology/Whitaker  
College

Jeffrey H. Lang  
Associate Professor  
Department of Electrical  
Engineering and Computer  
Science

F. Thomson Leighton  
Associate Professor  
Department of Mathematics

Victor Li  
Associate Professor  
Department of Civil  
Engineering

Thomas W. Malone  
Associate Professor  
Sloan School of Management

Terry A. Marsh  
Associate Professor  
Sloan School of Management

John D. W. Morecroft  
Associate Professor  
Sloan School of Management

Alan C. Nelson  
Associate Professor  
Department of Nuclear  
Engineering

W. Russell Neuman  
Associate Professor  
Department of Political  
Science

Terry P. Orlando  
Associate Professor  
Department of Electrical  
Engineering and Computer  
Science

Anthony T. Patera  
Associate Professor  
Department of Mechanical  
Engineering

Steven Pinker  
Associate Professor  
Department of Psychology

Ram T. S. Ramakrishnan  
Associate Professor  
Sloan School of Management

Terry A. Ring  
Associate Professor  
Department of Materials  
Science and Engineering

Harriet Ritvo  
Associate Professor  
Writing Program  
Department of Humanities

Paola M. Rizzoli  
Associate Professor  
Department of Earth,  
Atmospheric and Planetary  
Sciences

Rodolfo R. Rosales  
Associate Professor  
Department of Mathematics

Herbert H. Sawin  
Associate Professor  
Department of Chemical  
Engineering

Paul D. Sclavounos  
Associate Professor  
Department of Ocean  
Engineering

S. Shyam Sunder  
Associate Professor  
Department of Civil  
Engineering

Gary E. Wnek  
Associate Professor  
Department of Materials  
Science and Engineering

Richard E. Zippel  
Associate Professor  
Department of Electrical  
Engineering and Computer  
Science

Victor W. Zue  
Associate Professor  
Department of Materials  
Science and Engineering

#### To Assistant Professor

Antonio Sanchez-Calle  
Assistant Professor  
Department of Mathematics

#### CHANGES OF APPOINTMENT

Thomas J. Allen  
Gordon Y. Billard Fund  
Professor of Management  
Sloan School of Management

Suzanne Berger  
Ford International Professor  
of Political Science  
Department of Political  
Science

E. Cary Brown  
Head of Foreign Languages and  
Literatures Section, Associate  
Dean of the School of Humanities  
and Social Science and Professor  
of Economics

Walter Dean Burnham  
Arthur and Ruth Sloan Professor  
of Political Science  
Department of Political Science

Richard L. Cartwright  
Department Head of Linguistics  
and Philosophy and Professor  
of Philosophy  
Department of Linguistics and  
Philosophy

Eugene E. Covert  
Department Head and Professor of  
Aeronautics and Astronautics  
Department of Aeronautics and  
Astronautics

Ernest G. Cravalho  
Edward Hood Taplin Professor  
of Medical Engineering  
Harvard-MIT Division of Health  
Sciences and Technology

Peter A. Diamond  
Department Head and Professor of  
Economics  
Department of Economics

Mildred S. Dresselhaus  
Institute Professor and  
Professor of Electrical  
Engineering  
Department of Electrical  
Engineering and Computer Science

Edward H. Farhi  
Class of 1956 Career Development  
Assistant Professor of Physics  
Department of Physics

Maurice Fox  
Department Head, Biology and  
Professor of Biology  
Department of Biology

Rita B. Goldberg  
Assistant Professor  
Literature Section  
Department of Humanities

Timothy G. P. Gutowski  
Alcoa Assistant Professor of  
Mechanical Engineering  
Department of Mechanical  
Engineering

Joe Haldeman  
Adjunct Professor of Fiction  
in Humanities Writing Program  
Department of Humanities

Steven R. Hall  
Boeing Assistant Professor  
Department of Aeronautics  
and Astronautics

R. John Hansman  
Esther and Harold E. Edgerton  
Assistant Professor  
Department of Aeronautics  
and Astronautics

David E. Hardt  
Director of Laboratory for  
Manufacturing and Productivity  
and Associate Professor  
Department of Mechanical  
Engineering

Oliver S. D. Hart  
Professor  
Department of Economics

Arnoldo C. Hax  
Alfred P. Sloan Professor  
of Management  
Sloan School of Management

Richard O. Hynes  
Associate Department Head, and  
Professor of Biology  
Department of Biology

Jack L. Kerrebrock  
Associate Dean of Engineering  
and Richard Cockburn Maclaurin  
Professor of Aeronautics  
and Astronautics

Samuel J. Keyser  
Associate Provost for  
Educational Programs and  
Policy in Office of the  
Provost and Professor of  
Linguistics and Philosophy

Robert H. Kingston  
Adjunct Professor of  
Electrical Engineering  
Department of Electrical  
Engineering and Computer  
Science

Stanley B. Kowalski  
Professor of Physics  
Department of Physics

Marcel La Follette  
Assistant Professor  
Writing Program  
Department of Humanities

Raphael C. Lee  
Karl R. Van Tassel Career  
Development Assistant  
Professor of Electrical  
Engineering  
Department of Electrical  
Engineering and Computer  
Science

Lowell Lindgren  
Head of Music Section and  
Associate Professor of Music  
Department of Humanities

Francis E. Low  
Institute Professor and  
Professor of Physics

Margaret L. A. MacVicar  
Dean for Undergraduate  
Education in Office of the  
Provost and Cecil and Ida  
Green Professor of Education  
and Professor of Physical  
Sciences  
Department of Physics

Thomas L. Magnanti  
George Eastman Professor of  
Management Science  
Sloan School of Management

Thomas W. Malone  
Douglas Drane Career  
Development Associate  
Professor in Information  
Technology and Management  
Sloan School of Management

Roger G. Mark  
Acting Co-Director of the  
Harvard-MIT Division of Health  
Sciences and Technology and  
Matsushita Professor of  
Electrical and Mechanical  
Engineering in Medicine  
Department of Electrical  
Engineering and Computer  
Science

David H. Marks  
Department Head and Professor  
of Civil Engineering  
Department of Civil  
Engineering

Barbara J. Meyer  
Whitehead Institute Career  
Development Assistant  
Professor of Biology  
Department of Biology

Bruce R. Musicus  
Rockwell International Career  
Development Assistant  
Professor of Electrical  
Engineering  
Department of Electrical  
Engineering and Computer  
Science

Nicholas P. Patrikalakis  
Assistant Professor of Ocean  
Engineering

Daniel Roos  
Director of Center for  
Technology, Policy and  
Industrial Development and  
Japan Steel Industry  
Department of Civil  
Engineering

Mary P. Rowe  
Adjunct Professor of  
Management  
Sloan School of Management

Martin F. Schlecht  
Joseph F. and Nancy P.  
Keithley Career Development  
Assistant Professor  
Department of Electrical  
Engineering and Computer  
Science

S. Shyam Sunder  
Gilbert W. Winslow Career  
Development Associate  
Professor  
Department of Civil  
Engineering

R. Erik Spjut  
John Chipman Assistant  
Professor of Chemical Process  
Metallurgy  
Department of Materials  
Science and Engineering

Donca Steriade  
Assistant Professor  
Department of Linguistics  
and Philosophy

Joseph M. Sussman  
Director of Center for  
Transportation Studies and  
Professor of Civil Engineering

Judith Tendler  
Professor of Political Economy  
Department of Urban Studies  
and Planning

Daniel I. C. Wang  
Director, Biotechnology  
Processing Engineering Center  
and the Chevron Professor of  
Chemical Engineering

Scott Weinstein  
Associate Professor  
Department of Linguistics  
and Philosophy

Martin Weitzman  
Mitsui Professor in Problems  
of Contemporary Technology and  
Professor of Economics  
Department of Economics

Earle R. Williams  
Assistant Professor of  
Meteorology  
Department of Earth,  
Atmospheric and Planetary  
Sciences

Rosalind Williams  
Assistant Professor  
Writing Program  
Department of Humanities

Bernhardt J. Wuensch  
TDK Professor  
Department of Materials  
Science and Engineering

Richard J. Wurtman  
Director of Clinical Research  
Center and Professor of  
Applied Biological Sciences

Zenon S. Zannetos  
Professor of Management and  
Senior Associate Dean for  
Development  
Sloan School of Management

#### NEW FACULTY APPOINTMENT

##### Professor

Richard Kayne  
Professor  
Department of Linguistics and  
Philosophy

##### Associate Professor

Rohan Abeyaratne  
Associate Professor  
Department of Mechanical  
Engineering

Scott Weinstein  
Associate Professor  
Department Of Linguistics  
and Philosophy

##### Assistant Professor

Bruce E. Beall  
Assistant Professor of  
Physical Education and Head  
Coach/Director of Crew  
Athletic Department

Michael A. Celia  
Assistant Professor  
Department of Civil  
Engineering

Brent H. Cochran  
Assistant Professor  
Department of Biology

Mark Drela  
Assistant Professor  
Department of Aeronautics  
and Astronautics

William K. Durfee  
Assistant Professor  
Department of Mechanical  
Engineering

Howard Eiland  
Assistant Professor  
Literature Section  
Department of Humanities

Robert S. Gibbons  
Assistant Professor  
Department of Economics

Michael B. Giles  
Assistant Professor  
Department of Aeronautics  
and Astronautics

Daniel E. Hastings  
Assistant Professor  
Department of Aeronautics  
and Astronautics

Roger T. Howe  
Assistant Professor  
Department of Electrical  
Engineering and Computer  
Science

Steven H. Kim  
Assistant Professor  
Department of Mechanical  
Engineering

B. Gabriel Kotliar  
Assistant Professor  
Department of Physics

Richard K. Larson  
Assistant Professor  
Department of Linguistics  
and Philosophy

Lode Li  
Assistant Professor,  
Management Science  
Sloan School of Management

Lisa M. Lynch  
Assistant Professor,  
Industrial Relations  
Sloan School of Management

Tod Machover  
Assistant Professor  
Department of Architecture

Sue McNeil  
Assistant Professor  
Department of Civil  
Engineering



Amiram Moshaiov  
Assistant Professor  
Department of Ocean  
Engineering

Shahryar Motakef  
Assistant Professor  
Department of Mechanical  
Engineering

Patricia C. O'Brien  
Assistant Professor  
Sloan School of Management

Carl F. K. Pearson  
Assistant Professor  
Department of Mathematics

Janos Polonyi  
Assistant Professor  
Department of Physics

Danny Quah  
Assistant Professor  
Department of Economics

Nancy L. Rose  
Assistant Professor  
Sloan School of Management

Hee-Sup Shin  
Assistant Professor  
Department of Biology

David Shmoys  
Assistant Professor  
Department of Mathematics

Nathan O. Siu  
Assistant Professor  
Department of Nuclear  
Engineering

Alexander H. Slocum  
George Macomber Career  
Development Assistant  
Professor  
Department of Civil  
Engineering

Duvvuru Sriram  
Assistant Professor  
Department of Civil  
Engineering

Steven W. Stahler  
Assistant Professor  
Department of Physics

Charles Stewart III  
Assistant Professor  
Department of Political  
Science

John L. Tonry  
Assistant Professor  
Department of Physics

Richard M. Valeyly  
Assistant Professor  
Department of Political  
Science

N. Venkatraman  
Assistant Professor  
Sloan School of Management

Andreas Hubertus Von Flotow  
Assistant Professor  
Department of Aeronautics  
and Astronautics

Nicholas Warner  
Assistant Professor  
Department of Mathematics

Jacob White  
Assistant Professor  
Department of Electrical  
Engineering and Computer  
Science

Jack Wisdom  
Assistant Professor  
Department of Earth,  
Atmospheric and Planetary  
Sciences

Adjunct Professor

Don P. Clausing  
Adjunct Professor  
Department of Electrical  
Engineering and Computer  
Science

Visiting Professor

Melvyn Berger  
Visiting Professor  
Department of Mathematics

Haim Brezis  
Visiting Professor  
Department of Mathematics

Jean-Loup Delcroix  
Visiting Professor  
Department of Electrical  
Engineering and Computer  
Science

Perci Diaconis  
Visiting Professor  
Department of Mathematics

Shmuel Einav  
Visiting Professor  
Department of Mechanical  
Engineering

John E. Ffowcs Williams  
Visiting Professor  
Department of Aeronautics  
and Astronautics

William A. Gamson  
Visiting Professor  
Department of Political  
Science

Gerald Holton  
Visiting Professor  
Program in Science, Technology  
and Society

Ding Chong Lu  
Visiting Professor  
Department of Mechanical  
Engineering

Shlomo Maital  
Visiting Professor  
Sloan School of Management

Nicolas S. Majluf  
Visiting Professor  
Sloan School of Management

Thomas E. Pearsall  
Visiting Professor  
Writing Program  
Department of Humanities

Nicolaos S. Platakis  
Visiting Professor  
Department of Materials  
Science and Engineering

Wayne A. Pryor  
Visiting Professor  
Department of Earth,  
Atmospheric and Planetary  
Science

Pradeep K. Rohatgi  
Visiting Professor  
Department of Materials  
Science and Engineering

Steven C. Salop  
Visiting Professor  
Department of Economics

Ronald F. Scott  
Visiting Professor  
Department of Civil  
Engineering

Eytan M. Sheshinski  
Visiting Professor  
Department of Economics

Adolf M. Vogt  
Visiting Professor  
Department of Architecture

Visiting Associate Professor

Mark J. Balas  
GenRad Visiting Associate  
Professor  
Department of Electrical  
Engineering and Computer  
Science

Seyla Benhabib  
Visiting Associate Professor  
Department of Political  
Science

Giuseppe Bertin  
Visiting Associate Professor  
Department of Mathematics

John M. Abowd  
Visiting Associate Professor  
Department of Economics

Avishai Ceder  
Visiting Associate Professor  
Department of Civil  
Engineering

Amjad H. Dilawari  
Visiting Associate Professor  
Department of Materials  
Science and Engineering

Fereydoon Family  
Visiting Associate Professor  
Department of Chemistry

Emmanuel D. Farjoun  
Visiting Associate Professor  
Department of Mathematics

John Forester  
Visiting Associate Professor  
Department of Urban Studies  
and Planning

Hideo Fujimoto  
Visiting Associate Professor  
Department of Mechanical  
Engineering

David M. Galenson  
Visiting Associate Professor  
Department of Economics

Thomas C. Hubka  
Visiting Associate Professor  
Department of Architecture

Asashi Kitamoto  
Visiting Associate Professor  
Department of Nuclear  
Engineering

Kaino Koji  
Visiting Associate Professor  
Department of Mechanical  
Engineering

Jeffrey H. Kulick  
Visiting Associate Professor  
Department of Architecture

Bent Orsted  
Visiting Associate Professor  
Department of Mathematics

Bjornar Pettersen  
Visiting Associate Professor  
Department of Ocean  
Engineering

Roger Simmonds  
Visiting Associate Professor  
Department of Urban Studies  
and Planning

Martha Smith  
Visiting Associate Professor  
Department of Mathematics

Angela E. Stent  
Visiting Associate Professor  
Department of Political  
Science

Knut T. Taraldsen  
Visiting Associate Professor  
Department of Linguistics  
and Philosophy

James G. Ward  
Visiting Associate Professor  
Naval Science

Leslie K. Weisman  
Visiting Associate Professor  
Department of Architecture

Stanley B. Zdonik, Jr.  
Visiting Associate Professor  
Sloan School of Management

Visiting Assistant Professor

William T. Dickens  
Visiting Assistant Professor  
Sloan School of Management

Sumantra Ghoshal  
Visiting Assistant Professor  
of Management  
Sloan School of Management

Deborah L. Gladstein  
Visiting Assistant Profesosr  
Sloan School of Management

E. Allen Jacobs  
Visiting Assistant Professor  
Sloan School of Management

Stephen S. Morgenthaller  
Visiting Assistant Professor  
Statistics Center

Yechiel Rosenfeld  
Visiting Assistant Professor  
Department of Civil  
Engineering

Mary Jane Shultz  
Visiting Assistant Professor  
Department of Chemistry

Rene M. Stulz  
Visiting Assistant Professor  
Sloan School of Management

AWARD

Franco Modigliani  
Institute Professor  
Killian Award  
Lecturer 1985-1986

ADMINISTRATION

DEATHS

James F. McTighe  
Senior Staff Accountant  
Office of the Bursar

Charles E. Wilkins  
Route Supervisor, Building  
Services  
Superintendent's Office

RETIREMENTS

Irving A. Berstein  
Program Officer for  
Research and Development  
Harvard-MIT Division of Health  
Sciences and Technology

Alfred Cabral  
Sergeant  
Campus Police

Seibert O. Callender  
Assistant Manager  
Superintendent's Office

Calvin D. Campbell  
Staff Photojournalist  
News Office

Eugene R. Chamberlain  
International Students Advisor  
and Associate Dean  
Dean for Student Affairs

Frances A. Chandler  
Coordinator of Special  
Projects  
Alumni Association

Mary-Louise Daly  
Librarian  
Libraries

Richard T. Greenough  
Assistant Supervisor,  
Grounds Services  
Physical Plant

Inez B. Hazel  
Systems Programmer  
Operations and Systems

Charles T. Jennings  
Route Supervisor,  
Building Services  
Superintendent's Office

Peter Johnson  
Supervisor, Mechanical  
Services  
Superintendent's Office

Doris M. Marzoni  
Accounting Officer  
Comptroller's Accounting  
Office

Richard F. McKay  
Superintendent of Utilities  
and Engineering  
Physical Plant

Julia C. McLellan  
Senior Associate Director  
of Admissions  
Office of Admissions

Joseph B. Paiva, Jr.  
Staff Accountant  
Comptroller's Accounting  
Office

Ernest R. Pariser  
Associate Director  
Sea Grant College Program

Albert Pellecchia  
Supervisor  
Graphic Arts

Harold W. Roberts  
Route Supervisor,  
Building Services  
Superintendent's Office

#### RESIGNATIONS

Salim M. Alani  
Auditor  
Audit Division

Barbara Alpert  
Senior Analyst Programmer  
Administrative Systems

Nelson Armstrong  
Associate Director  
Office of Admissions

Kenneth M. Arsenault  
Property Auditor  
Office of Facilities  
Management Systems

James J. Assad  
Assistant to the Bursar,  
Loan Collection  
Office of the Bursar

Benjamin A. Bernick  
Food Production Supervisor  
Food Services

Scott A. Berry  
Unit Manager  
Food Services

Laurence H. Bishoff  
Executive Director, MIT  
Health Plan, and Acting Head  
of the Medical Department

Robert G. Boes  
Assistant Director  
Office of Facilities  
Management Systems

Ellen A. Bolick  
Administrative Assistant  
Technology and Policy Program

Kevin Bouchard  
Gallery Manager  
Committee on the Visual Arts

Paul E. Boutin  
Systems Coordinator  
Operations and Systems

Judith M. Brennan  
Administrative Coordinator  
Housing

John A. Carta  
Auditor  
Audit Division

Richard J. Cerrato  
Assistant Director  
Housing and Food Services

Andrea M. Chapman  
Assistant to the Dean  
Dean for Student Affairs

Marjorie W. Chryssostomidis  
Librarian  
Libraries

Carole A. Clark  
Administrative Assistant  
Administrative Systems

Daniel J. Clark, Jr.  
Supervisor, Mechanical  
Services  
Physical Plant

Mary E. Collins  
Assistant Marketing Manager  
MIT Press

Roger L. Conover  
Acquisition Editor  
MIT Press

Ann M. Conway  
Senior Staff Accountant  
Treasurer's Office

Janice R. Cooper  
Assistant Dean for Student  
Affairs  
Dean for Student Affairs

Loren Cox  
Director, Center for Energy  
Policy Research  
Sloan School of Management

Irvin F. Curtis  
Administrative Assistant  
Department of Mechanical  
Engineering

Emily J. Cushman  
Assistant to the Director  
Telecommunications Systems

Thomas L. Davenport  
Applications Programmer  
Department of Materials  
Science and Engineering

Patricia A. DePamphilis  
Benefits Associate  
Personnel Office

Dorothy H. Desimone  
Librarian  
Libraries

Andre J. Desimone  
Admissions Counselor  
Office of Admissions

Jacqueline Detweiler  
Area Supervisor  
Food Services

Barbara Dullea  
Operations Manager,  
Conferences and Seminars  
Center for Advanced  
Engineering Study

Lisa M. Ehrmann  
Computer Operations Assistant  
Office of Admissions

Karen A. Engelbourg  
Assistant Director  
Development Office

Kathleen F. Finklestein  
Manager of Administrative  
Operations  
Alumni Association

Albert H. Forest  
General Manager  
Endicott House

Martha L. Fox  
Administrative Assistant  
Department of Mathematics

James T. Gabbert, Jr.  
Coordinator, Masters Program  
Sloan School of Management

Elizabeth Goodman  
Assistant Managing Editor,  
Sloan Management Review  
Sloan School of Management

Rona H. Gregory  
Librarian  
Libraries

David G. Grubbs  
Assistant Network Manager  
Telecommunications Systems

Peter Gwynne  
Managing Editor,  
Technology Review  
Alumni Association

Jana Heffernan  
Archival/Manuscript Specialist  
Libraries

Kay Henry  
Coordinator  
of Reunion Programs  
Alumni Association

Astrid A. Hiemer  
Administrative Officer  
Center for Advanced  
Visual Studies

Richard E. Higham  
Senior Personnel Officer  
Personnel Office

Deborah A. Hoover  
Executive Director,  
Council for the Arts at MIT  
Office of the President

Stacy E. Hynes  
Donor Relations Coordinator  
Communications/Resource  
Development

Jenni Johnson  
Supervisor, Undergraduate  
Office  
Department of Physics

Nancy J. Kaufer  
Records Management Officer  
Libraries

Kenneth F. Keefe  
Senior Analyst Programmer  
Administrative Systems

Charles N. Kennedy  
Analyst Programmer  
Administrative Systems

Paula A. Kiberstis  
Editor  
MIT Press

Kathleen R. Klingenberg  
Systems Coordinator  
Personnel Office

Richard L. Kort  
Librarian  
Libraries

Deborah L. Kram  
Librarian  
Libraries

James M. Kyed  
Librarian  
Libraries

Joan T. Kyhos  
Assistant Director  
Office of Sponsored Programs

John F. Lanigan  
Senior Applications Programmer  
Office of Facilities  
Management Systems

Laura J. Letourneau  
Technical Writer  
Administrative Systems

Elizabeth R. Lawry  
Technical Writer  
Information Services

Jeannine M. LeBlanc  
Supervisor, Support Services  
Purchasing and Stores

Judith F. Levy  
Assistant to the Bursar,  
Loan Collections  
Office of the Bursar

Genevieve MacLellan  
Assistant Editor  
MIT Press

Diane E. McLaughlin  
Budget Officer  
Fiscal Planning  
and Budget Office

Marion McNair  
Space Analyst  
Office of Facilities  
Management Systems

Ann E. McNamara  
Journals Editorial and  
Production Manager  
MIT Press

John F. McNeil  
Industrial Liaison Officer  
Industrial Liaison Program

Margery Meadow  
Technical Writer  
Project Athena

Pearline D. Miller  
Assistant Director, Office of  
Minority Education  
Dean for Student Affairs

Linda E. Morecroft  
Applications Development  
Programmer  
Project Athena

Gioia M. Morongell  
Manager for Marketing  
and Member Services  
Medical Department

John B. Morway  
Administrative Officer  
Department of Physics

Margaret Mubiru-Musoke  
Assistant Director,  
Undergraduate Research  
Opportunities Program  
Office of the Provost

Cornelius J. Murphy  
Assistant Supervisor,  
Grounds Services  
Superintendent's Office

Glenn H. Myers  
Applications Programmer  
Comptroller's Accounting  
Office

Carole E. Nassif  
Staff Accountant  
Comptroller's Accounting  
Office

Lauren T. Norton  
Assistant to the Director  
Alumni Association

Marianne E. O'Donnell  
Associate Director for  
Resource Development  
Center for Real Estate  
Development

Beth-Anne Oliver  
Supervisor  
Food Services

Miriam Palmerola  
Manager, Computer  
Composition Department  
MIT Press

Barbara J. Pease  
Systems Programmer  
Project Athena

Barry Pieciul  
House Manager  
Housing

Jennifer Pinkus  
Applications Consultant  
Project Athena

R. Winslow Poor  
Manager, Animal Facilities  
Division of Comparative  
Medicine

John M. Poverchuk  
Area Manager  
Administrative Systems

Kathleen S. Reid  
Administrative Officer  
Laboratory of Architecture  
and Planning

Bryan J. Ricketson  
Analyst Programmer  
Administrative Systems

Michael D. Roper  
Post-Production Manager  
and Staff Producer  
Office of the Provost

Beth A. Rosner  
Advertising and Promotion  
Manager  
MIT Press

John F. Rutledge  
Assistant Operations Manager  
Housing

Susan E. Sanderson  
Budget Officer  
Fiscal Planning and Budget  
Office

Andrew E. Schwartz  
Manager of Training  
Information Services

Shlomo Segev  
Programmer Analyst  
Office of Facilities  
Management Systems

Niti Seth  
Video Resources Specialist  
Department of Urban Studies  
and Planning

Christine Simonsen  
Director, Conferences and  
Seminars  
Center for Advanced  
Engineering Study

Arthur A. Smith, Jr.  
General Counsel  
Office of Vice President  
for Research

Inez E. Steele  
Administrative Assistant  
Center for Real Estate  
Development

Jane A. Steenstra  
Donor Relations Coordinator  
Communications/Resource  
Development

Merrily D. Sterns  
Assistant Director  
Office of Sponsored Programs

Maryann Taylor  
Associate Director  
for Gifts and Grants  
Center for Real Estate  
Development

Scott B. Thomson  
Technical Assistant  
Harvard/MIT Division of Health  
Sciences and Technology

Kathryn L. Tighe  
Child Care Administrator  
Child Care Office

Patricia M. Tyler  
Journals Advertising  
and Exhibits Manager  
MIT Press

Barbara T. VanScoyoc  
Senior Technical Writer  
Information Services

Linda Vaughan  
Associate Dean, Student  
Assistance Services  
Dean for Student Affairs

Herkus W. Von Letkemann  
Senior Systems Analyst  
Information Services

Zita M. Wenzel  
Manager, Microcomputer Center  
Information Services

Mary B. Wyer  
Coordinator, Women's Studies  
School of Humanities and  
Social Science

Karen Yegian  
Budget Officer  
Fiscal Planning and Budget  
Office

Stephen H. Young  
Facilities Coordinator  
Division of Comparative  
Medicine

Bruce A. Zabierek  
Analyst Programmer  
Administrative Systems

#### NEW APPOINTMENTS

Douglas Alan  
Systems Programmer  
Operations and Systems

Robin Alberts  
Route Supervisor,  
Building Services  
Physical Plant

Richard P. Anthony  
Staff Writer/Editor  
Communications/Resource  
Development

Sandra N. Anthony  
Coordinator,  
Senior Executive Program  
Sloan School of Management

Jonathan D. Arnold  
Applications Development  
Programmer  
Project Athena

Gregory Arsenault  
Programming Analyst  
Fiscal Planning  
and Budget Office

James J. Assad  
Assistant to the  
Bursar, Loan Collection  
Office of the Bursar

Laura J. Ayr  
Journals Advertising  
and Exhibits Manager  
MIT Press

Heather Ballinger  
Administrative Assistant  
Department of Materials  
Science and Engineering

William J. Barrett  
Purchasing Agent  
Purchasing and Stores

Susan E. Bello  
Librarian  
Libraries

Sarah Bingman  
Development Officer  
School of Engineering

Tim E. Blimptis  
Assistant to the Treasurer  
Treasurer's Office

Helen M. Blue  
Production Manager,  
Communications  
Campus Information Services

Marilyn Bodnar  
Administrative Officer  
Dean for Student Affairs

Rui Borges  
Route Supervisor,  
Building Services  
Physical Plant

Damon E. Bostick  
Consultant  
Information Services

Lisa A. Boyle  
Business Manager  
Endicott House

David A. Bridgham  
Assistant Network Manager  
Telecommunications Systems

Cynthia F. Brown  
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Studies Program  
School of Humanities  
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Timothy P. Browne  
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Media Laboratory

Jean B. Bruns  
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Alumni Fund  
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Neil G. Buckley, Jr.  
Administrative Coordinator  
Sloan School of Management

Roman J. Budzianowski  
Applications Development  
Programmer  
Project Athena

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Kenneth D. Campbell  
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News Office

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Systems and Records  
Personnel Office

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Sergeant  
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Eugenia Gordon  
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Development Office

Julian W. Green  
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Libraries

Kathleen A. Green  
Librarian  
Libraries

Cathy C. Greene  
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Libraries

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Center for Real Estate  
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Industrial Internship Program  
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Engineering and Computer  
Science

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MIT Press

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MIT Press

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Industrial Liaison Program

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Committee on the Visual Arts

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Fiscal Planning and  
Budget Office

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Treasurer's Office

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and Social Science

Row-Row Selman  
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Department of Ocean  
Engineering

Deborah Shea  
Archival/Manuscript Specialist  
Libraries

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Center for Advanced  
Engineering Study

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Undergraduate  
Research Opportunities Program  
Office of the Provost

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Analyst Programmer  
Comptroller's Accounting  
Office

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Staff Accountant  
Comptroller's Accounting  
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Admissions Counselor  
Office of Admissions

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Assistant Dean for Student  
Affairs,  
Student Assistance Services  
Dean for Student Affairs

Dallas M. Slawter  
Assistant to the Director,  
Office of Minority Education  
Dean for Student Affairs

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Assistant to the Secretary  
of the Corporation  
Office of the President  
Secretary of the Corporation

Clare B. Stanley  
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Administrative Systems

Jane A. Steenstra  
Donor Relations Coordinator  
Communications/Resource  
Development

Jacqueline A. Stewart  
Manager, User Services  
Project Athena

Patricia A. Sullivan  
Route Supervisor,  
Building Services  
Physical Plant

Sambasivan Suresh  
Facilities Coordinator  
Office of Facilities  
Management Systems

Maria Tantoulos  
Staff Accountant  
Comptroller's Accounting  
Office

Wayne T. Turner  
Space Analyst  
Office of Facilities  
Management Systems

Laura VanDam  
Staff Writer/Editor  
Alumni Association

Marie T. Vander Sande  
Industrial Liaison Officer  
Industrial Liaison Program

Terry D. Vaughn  
Acquisition Editor-Economics  
Business and Public Policy  
MIT Press

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Special Assistant to the Dean  
Dean for Student Affairs

Jacalyn D. Walker-Sharp  
Coordinator, Management  
of Technology Program  
Sloan School of Management

Gregory D. Whall  
Administrator for Computer  
Operations and Systems  
Applications  
Leadership Gifts

Pamela S. Williams  
Auditor  
Audit Division

Grazia K. Wilson  
Associate Bursar  
for Student Services  
Office of the Bursar

John S. Wilson  
Associate, Analytical Studies  
and Planning Group  
Office of the President

H. Lauren Zachmann  
Administrative Assistant  
Media Laboratory

## CHANGES

Maija K. Ahlquist  
Administrative Assistant to  
the Department Head  
Department of Biology

Rosalie M. Allen  
Administrative Assistant  
Office of the Summer Session

Beth L. Anderson  
Training and Consulting  
Specialist  
Project Athena

Anne E. Armitage  
Administrative Assistant  
Program in Science,  
Technology, and Society

Shirley K. Baker  
Associate Director for  
Public Services  
Libraries

Heather D. Ballinger  
Fiscal Officer  
Department of Materials  
Science and Engineering

Dennis Baron  
Transmission Manager  
Telecommunications Systems

Joanne C. Barrett  
Assistant Accounting Officer  
Comptroller's Accounting  
Office

Beth L. Barovick  
Assistant Journals Manager  
MIT Press

Donna M. Behmer  
Director,  
Administration and Finance  
Sloan School of Management

Paul E. Boutin  
Systems Programmer  
Operations and Systems

Sheelah Britt  
Librarian  
Libraries

Jean M. Broderick  
Administrative Assistant to  
the Chairman  
Office of the President  
Office of the Chairman of the  
Corporation

Catherine M. Burke  
Assistant Operations Manager  
Telecommunications Systems

Robert M. Byers, Sr.  
Administrative Staff  
Campus Information Services

Kathleen E. Carney  
Analyst Programmer  
Administrative Systems

Jeanne Cavanaugh  
Manager of Training  
Information Services

Edward J. Cerrato  
Chef  
Endicott House

Peter N. Cerundolo  
Assistant Director  
Industrial Liaison Program

Marcia V. Chapman  
Administrative Officer  
Operations Research Center

Eleanor Chin  
Coordinator,  
Executive Programs  
Sloan School of Management

Katherine R. Cochrane  
Administrative Officer  
Alumni Association

Marcia E. Conroy  
Assistant Director  
for Education and  
Community Relations  
Libraries

James G. Cronburg  
Planning Officer  
Planning Office

Nadine H. Cruz  
Analyst Programmer  
Administrative Systems

Steve L. Csipke  
Senior Technical Writer  
Administrative Systems

Cecilia R. D'Oliveira  
Assistant Director of  
Information Systems Planning  
Information Systems

D. Hugh Darden  
Associate Treasurer and  
Director, Planned Gifts and  
Legal Affairs  
Treasurer's Office

Ree Dawson  
Assistant to the Director  
Information Services

Susan Deford-Offner  
Manager, Special Investments,  
and Assistant Director  
of Real Estate  
Treasurer's Office

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Senior Industrial  
Liaison Officer  
Industrial Liaison Program

June E. Desmarais  
Staff Accountant  
MIT Press

Jacqueline Detweiler  
Area Food Service Supervisor  
Food Services

Neil W. Didriksen  
Director  
Leadership Gifts

Robert G. DiIorio  
Associate Director  
News Office

Kristin N. Djourup  
Librarian  
Libraries

Thomas E. Donnelly  
Property Disposal Officer  
Property Office

Webb F. Elkins  
Director of Alumni  
Relations/Secretary  
of the Alumni Association  
Alumni Association

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Applications Development  
Programmer  
Project Athena

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Undergraduate Academic  
Support Office  
Dean for Student Affairs

Barbara M. Fienman  
Director of Campus Activities  
Dean for Student Affairs

Leslie A. Finck  
Analyst Programmer  
Administrative Systems

Gayle M. Fitzgerald  
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Campus Information Services

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General Manager  
Endicott House

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Campus Police

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Librarian  
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MIT Health Plan  
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Treasurer's Office

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Randall W. Winchester  
Assistant Transmission Manager  
Telecommunications Systems

Michael W. Yeates  
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Collections  
Libraries

Judy Young  
Analyst Programmer  
Administrative Systems



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## Provost

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At the conclusion of my first year as Provost, I would like to make a few brief observations about what I view as the accomplishments of my first year in office and, more importantly, the major challenges in the year ahead.

Before proceeding to address these two subjects, I wish to express my appreciation to various individuals who have made these accomplishments possible. First, I note that my predecessor and friend, Francis Low, left the affairs of the Office of the Provost in very good order, thus permitting an easy transition for me. A year as Provost has confirmed my opinion that Francis accomplished a great deal of benefit for the Institute and deserves the entire community's gratitude. Second, all the senior members of the MIT administration, especially the academic deans, have made every effort to adjust to a new Provost whose foibles are widely known. The cooperation and dedication of these individuals are the basis of achieving needed improvements in the Institute's education and research programs. Finally, I thank the staff of the Office of the President and Provost who have not only been loyal and supportive but also contributed humor and encouragement in each business day.

What do I judge to be the important accomplishments of the past year? A partial list follows.

1. Continued strengthening of the five-year planning process as a vehicle for establishing a baseline for where we are going and what we believe to be of greatest importance to education and research excellence.
2. The pursuit of several undergraduate educational initiatives, especially the Commission on Engineering Education, the review of the undergraduate Humanities, Arts, and Social Sciences requirement, and improvements for the freshman year. While much remains to be done, an excellent start has been made.
3. Successful reorganization of the Office of the Provost with the establishment of a new Dean for Undergraduate Education and the transfer of the Office of the Dean for Student Affairs to the Provost's Office. The Institute is most fortunate that Jay Keyser and Margaret MacVicar have respectively accepted the positions of Associate Provost for Educational Programs and Policy and Dean for Undergraduate Education. Together with Shirley McBay, Dean for Student Affairs, and Frank Perkins, Dean of the Graduate School, they are addressing educational issues inside and outside the classroom, from the freshman year through graduate school.
4. A subgroup of Academic Council under the chairmanship of Paul Gray has been established to begin the process of setting priorities for the upcoming Campaign for MIT. These academic priorities will be crucial for guiding our fund-raising efforts and for marshalling the participation of faculty and staff in the Campaign.
5. A number of programmatic initiatives have been successfully launched. Among the most notable changes are the following:

The Harvard-MIT Health Sciences and Technology Program has been reoriented in a way that better serves the participating institutions and permits a vigorous future.

A new academic department of Brain and Cognitive Sciences has been established as a part of Whitaker College from the existing Psychology Department and members of Whitaker College and others who are concerned with molecular neurobiology and other aspects of brain sciences. This new department signals a major intellectual initiative for the Institute in the coming years. I am extremely grateful to Kenneth A. Smith, Associate Provost and Vice President for Research, for his leadership in both of these new initiatives.

The Statistics Center has been given an expanded mission and transferred from the School of Science to the School of Humanities and Social Sciences. Further consolidation of this important activity with related effort in operations research and decision sciences can be expected in the future.

A welcome grant from the National Science Foundation has permitted the establishment of the Biotechnology Engineering Research Center, which will act as an important focal point for Institute-wide interest in the important area of biotechnology.

The interdisciplinary program in Polymer Science and Technology has given much-needed coherence to an increasingly important area of research at the Institute.

6. The MIT Patent Office has been completely reorganized into the Technology Licensing Office, thus giving a more appropriate emphasis to transferring technology invented by MIT researchers to industry in a manner which better serves the interests of the Institute and MIT researchers.
7. Responsibility for Lincoln Laboratory has been transferred from the President to the Provost. This transition has been made successfully. The report of the Faculty Committee on Lincoln Laboratory points to the need to strengthen the intellectual ties between Lincoln and the campus.

Despite these accomplishments, much remains to be done. The agenda for change at MIT that will assure our ability to maintain excellence in education and research into the twenty-first century is enormous. But perhaps the most important requirement is to maintain an atmosphere at the Institute that encourages excellence and innovation in our scholarly activities, especially for students and younger faculty, and maintains an air of excitement. The critical factor for establishing this atmosphere is the availability of adequate resources to support the many, worthwhile, new educational and research initiatives, which are proposed by the faculty and other members of the Institute community. The key for achieving adequate resources is the success of the upcoming Campaign at MIT. Accordingly, the single most important item on my agenda for the upcoming year is to mobilize the Institute community for the Campaign. In brief, this requires an agreement on Institute priorities, a realistic appreciation of what can be achieved in raising the needed resources, and an effective mechanism for providing appropriate support to the Campaign itself.

There are many other items that will be on the agenda of the Office of the Provost for the coming year. A few of these are:

- Deciding which new undergraduate education programs to launch and implement.
- Continuing the development of the planning process as a mechanism for identifying changes to ongoing academic programs.
- Giving continued attention to affirmative action issues and activities. The Institute's recent performance in hiring women and underrepresented minorities, especially for the faculty, is not what it should be at one of the nation's leading universities.
- Monitoring and adjusting to the impact of changes in the federal budget and in federal programs.

These and other subjects will receive growing attention during the coming year. Realizing significant progress depends upon the support of the faculty and staff of the Institute, and I trust that this support will be forthcoming during the 1986-87 academic year.

JOHN M. DEUTCH

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## Libraries

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During the year in which the Massachusetts Institute of Technology celebrated its quasiquintennial, the MIT Libraries reached two important milestones in its own history. The Libraries, founded in 1862, one year after the Institute, recorded the two millionth printed volume to be added to the collections and officially inaugurated the online system, named Barton after MIT's founder and first President, William Barton Rogers.

The two millionth volume celebration coincided with the 1986 meeting of the Corporation Visiting Committee for the Libraries and was the occasion for several activities including an open house in the Hayden Library courtyard for the MIT community. The two millionth volume, Abstraction and Specification in Program Development, was written by two faculty members in the Department of Electrical Engineering and Computer Science at MIT, Barbara H. Liskov and John V. Guttag, and published by the MIT Press. It was exhibited in the Science Library along with the first volume acquired by the Libraries, Report of the U.S. Commissioner of Patents for 1855, and the one millionth volume, a first edition of Whitman's Leaves of Grass, now part of the I. Austin Kelly, III, collection of rare books. It was noted that it took 106 years for the Libraries to acquire its first million volumes (1968) but only 18 for the second million. It was further noted, that at the one million volume celebration, a distinguished member of the computer science faculty was reputed to have said that there would never be a two millionth printed volume since technology would surely make books obsolete!

The juxtaposition of celebrations featuring books on the one hand and computers on the other, serves to emphasize the bimodal nature of research university libraries in the 1980's. At MIT, there is a continuing challenge caused by having to cope with a series of transitions: from printed text to digital text; from printed abstracts to online databases; from online to compact disc; from card catalogue to online public access catalogue. A critical issue involves predicting the length of time a particular transition will take and how best to utilize limited resources in dealing with both the old and the new. In the case of collections, it is likely that research libraries will never leave a bimodal environment and will have to deal with both printed and digitalized information for the foreseeable future. The days of the card catalogue, on the other hand, are clearly numbered and the chief question is when and how to close it. Planning for change, the allocation of resources to the implementation of the new while maintaining the old, and the coordination of all of this with the continuing pressures on the staff and on the acquisitions budget, will probably be the characteristic mode of life for the next decade.

### Planning and Development

The second detailed Five Year Plan for the MIT Libraries was prepared in the fall of 1985, building on the foundation of the first plan issued in 1983/84. The plan included an internal assessment of strengths and shortcomings and established a set of priorities for the Libraries over the next half-decade. The main features of the plan were the following: implementation of a public access online catalogue with authority control; linkage of the MIT Libraries' online systems with the campus information network; support for strengthening the collections, for extending information services, for developing a full-fledged preservation program, and for improving the physical environment for both people and collections. In addition, the Plan envisioned expanded acquisition of information in a variety of new formats including CD-ROM and optical disc, microcomputer software, and numerical databases in machine-readable form. Space needs included the expansion of Rotch Library and major renovations in the Hayden Library. The expansion of the Rotch Library of Architecture and Planning has been identified as having a very high priority for the Institute. A significant portion of the additional resources for collections, new programs and capital improvements that were identified in the Plan will, in all likelihood, have to come through the new development effort being launched by MIT or through the reallocation of existing resources. As part of the planning for a new fund-raising campaign, the Libraries established a set of priorities for both endowed and expendable funds. The major needs in endowment are funds for collection development, preservation, and capital equipment. The principal areas for expendable funds are (1) development of the online catalogue; (2) collection support in areas where the Libraries has failed to keep up with the growth of demand and in newly emerging fields of teaching and research; and (3) retrospective conversion of catalogue records still in card form to machine-readable form. In addition, the Libraries' priorities include the establishment, preferably through an endowment, of a minority librarian internship program.

Planning for an online public access catalogue with authority control accelerated during the year. A proposal suitable for presentation to outside funding agencies is anticipated by the summer of 1986. The major elements of this plan include support for additional equipment for both public and staff, upgrading and/or expansion of centralized space and equipment, development of a back-up system on CD-ROM, linkage

with Project Athena and the campus network, authority control, staff support during a three-year transition, and retrospective conversion. In the latter area, the two main categories of material that have been identified are currently-received serials and MIT theses written between 1964 and 1974.

Near the end of the academic year a decision was made to move toward the closing of the card catalogues. A planning effort was initiated in advance of, but in conjunction with, planning for a full online catalogue with the goal of closure during the 1986/87 academic year.

### Barton

During the year, the MIT Libraries' online system, Barton, began to make its presence felt throughout the campus. Following a plan that was carefully developed by the Implementation Coordinating Group (ICG), individual libraries were brought online for circulation functions at two to four week intervals beginning with the Aeronautics and Astronautics Library in March. This was followed by the Barker Engineering Library, the Dewey Library (social sciences and management), the Humanities and Science Libraries, and the Rotch Library of Architecture and Planning. By the end of the summer of 1986, all MIT libraries are expected to be up and running. The formal opening of the system took place during the Visiting Committee meetings in late May when the Chairman of the MIT Corporation charged out a circulating copy of the two millionth acquisition at the Barker circulation desk.

The diversity and range of activities that were required to reach the operational level of the online system are extremely impressive to contemplate and extend back over a three year period. Almost every aspect of the Libraries' operations and every single member of the staff were affected. The successful implementation of the system, although still ongoing at the end of the academic year, was a collective achievement of the highest quality.

During the past twelve months, there were numerous goals achieved and projects completed that were essential to the implementation of the Barton system. The Systems Office functioned, under the direction of the Systems Librarian, as a separate department for the first time. Among the major accomplishments were the initial load of monograph records into the system; establishment of a standard routine for the weekly loading of new records; installation of terminals and peripheral equipment in divisional and branch libraries; loading of patron files; and training and support for the staff in the public service areas.

At the beginning of the academic year, the Libraries undertook a major effort to place barcodes in all monographs for which records were then in the database. Approximately 250,000 individual barcodes were inserted. The project involved almost 200 members of the staff from every department and unit and was essentially completed over a two week period during which all of the public service units were closed for a half day. Online patron registration began in March and continued throughout the year. Major policy documents were developed dealing with fines, overdue notices and billing; with procedures for brief records and temporary records; with access levels and privacy guidelines; and with suspension of privileges. In the technical services area, considerable attention was devoted to continued improvement of the database; to solving problems emanating from the barcoding project; and to creating machine-readable holdings for multiple-volume titles.

Other significant developments in the systems area include the installation of a digital sharing device that enables simultaneous Acquisitions Department-Catalogue Department access to the Faxon LINX system; further extension of microcomputers throughout the Libraries and especially in the central administration; work on the serials fund commitment system, and on the microfiche listing, Serials in the MIT Libraries; and a major investigation into the area of electronic mail.

### Public Services

Staff of the public services units were deeply involved in a number of aspects of Geac implementation and are currently living through the transition from a manual to an online circulation environment. Nevertheless, the wide range and depth of services combined with a strong emphasis on collection development that are the hallmarks of the MIT Libraries continued throughout the year. The linkage of the Libraries to the campus network and the integration of library services into Project Athena remain as key objectives in the near future and efforts continued to bring them closer to actual operation. Public services staff worked closely with a senior undergraduate whose thesis topic was an investigation of student preferences for the electronic delivery of library services. An experiment to provide reference service and direct access to the Libraries' staff via electronic mail was initiated in the Barker Library using the network maintained by the Department of Electrical Engineering and Computer Science. Staffs in the Engineering, Humanities, and Science Libraries monitored and prepared written responses to the ongoing deliberations on undergraduate education at MIT. A modest increase in reference staff in the Humanities Library represented a recognition of that library being the place where many undergraduates make extensive use of the collections. The continuation of the undergraduate seminar on research methods is another commitment to the support of this important segment of the user community. Barton became an integral part of the continually-expanding menu of online reference services and the Libraries participated in an

evaluation of a new CD-ROM system being developed by the Digital Equipment Corporation. The Libraries, through the Computerized Literature Search Service, continued to offer to the MIT community extensive research assistance and consultation in the use of online databases.

A research effort with considerable long-term potential was begun in the Rotch Visual Collections under the title "Boston Project". Funded in part through Project Athena and with further support from the MIT Libraries and from the Council on Library Resources, this project is aimed at the development of a videodisc resource system that will deliver images from the library to the workstation. Building on knowledge gained under the Aga Khan Documentation Project, the current effort has produced a disc of some 7,000 slides and photographs of Boston architecture including slides from the 35mm and lantern slide collections, the Kepes/Lynch photographs, new photography of Boston, and 200 historic photographs loaned by the Fine Arts Department of the Boston Public Library. Another part of the project is developing a means of transmitting still frame images using high bandwidth communications systems. The CLR grant supports this effort that will include testing of cable, fibre optic networks, and microwave transmission.

#### Collection Management and Technical Services

One significant effect of the increased use of technology in research libraries, especially integrated library systems, has clearly been a much closer linkage between technical services and public services. This has certainly been the case at MIT and during the past year the staff of the Catalogue Department was deeply involved in all aspects of implementation of the Barton system. Members of that department along with the Acquisitions Department participated in the massive barcoding project. The portent of this trend continuing and expanding is viewed most positively especially as the Libraries moves toward a full online catalogue.

Among the more noteworthy events and happenings in the general area of collections was the appointment of the Libraries' first Preservation and Collections Librarian. The establishment of this position triggered a reorganization in two areas: the former Binding and Repair Section of the Acquisitions Department that will become the Binding and Repair Service, and the RetroSpective Collection formerly reporting to the Office of the Director, will both report to the new librarian.

Despite continued inflation, the number of volumes added to the collections continues to rise slowly. Some of this is due to benefits accruing from the NTAS (New Title Announcement Service) and some from internal reallocations. The Libraries also received a portion of the MIT grant from the John D. and Catherine T. MacArthur Foundation that will support acquisitions in arms control, disarmament, and international security over a three year period. A major concern arising during the year and continuing to have a disruptive effect on the serials acquisition program is discriminatory journal pricing. This practice, followed by a substantial number of European publishers, has caused alarming increases in the cost of foreign serials; under this system, North American institutional subscribers are charged considerably more, sometimes as much as 50-70 percent, than institutions in Europe. The Association of Research Libraries has decided to see whether collective action in some form, including the possibility of legal remedy, might be possible. In the meanwhile, there is the potentiality of a major cancellation program in order to cope with this situation.

The appointment of an Associate Head highlighted the activities of the Acquisitions Department along with the appointment of a new Assistant Acquisitions Librarian whose responsibilities include oversight of the exchange and gifts programs. The Department conducted a number of sales of duplicate and surplus books, many of which came from the collection in the Student Center Library. Income from these sales continues to be added to the Preservation Fund.

Among the significant achievements in the Catalogue Department was the full incorporation of the MARC Record Management System (MRMS) into the operations of the Department. Another major accomplishment was the intensive planning, testing, and record preparation undertaken to create a serials database of over 25,000 titles on the local Geac system. This is being accomplished by a complex load and merger of over 8,000 fully-catalogued OCLC serials, and approximately 22,000 brief serial records from the Faxon/Boston Library Consortium Union List. This joint project with two vendors, Geac and Faxon, is serving as a prototype for the interfacing of multi-level records for multiple sources. Other research libraries are already beginning to make use of the software developed in this endeavor. The project provides a practical and creative approach to the incremental building of an online catalogue through the utilization of temporary, brief bibliographic records and updated holdings pending the complete retrospective conversion of serials. For the first time in the history of the MIT Libraries, access will be provided to an integrated database of monographs and serials in the collections.

The MIT Libraries continued to benefit from the Title II-C program of the U.S. Office of Education. Following two years of support for retrospective conversion, manuscript processing, and preservation in the general area of science, technology, and society, MIT received its third grant in FY85 for support of cataloguing of the Roman Jakobson Collection in linguistics. Beginning in January 1986, the fourth consecutive year of II-C support underwrote the retrospective conversion of MIT publications from 1861 to 1974 and included funding for the cataloguing of a number of manuscript collections and for the creation

of preservation microfiche sets for Radiation Laboratory and Project Whirlwind reports that will be made available to the research community at large. The Libraries will receive a second year of support for this program beginning in January, 1987. A major result of this latest project will be to provide significantly better bibliographic access to the important research publications that have come from MIT over the past 125 years; this improvement will be reflected both in the bibliographic systems employed at the Institute as well as nationally and internationally, through the inclusion of these records in the OCLC and RLIN databases. Along with seven other major research libraries - UC Berkeley, Chicago, Cornell, Illinois, Stanford, Texas, and Wisconsin - MIT is involved and would be the lead institution in a cooperative retrospective conversion project in the general area of technology (Library of Congress "T" classification and DDC 600's). Fund raising efforts will commence shortly and, assuming that support will be found, the program will involve the coordinated conversion of about 160,000 records (34,000 of them from MIT) into the national databases. This is one of a number of programs being sponsored by the Association of Research Libraries under its national retrospective conversion program.

Preservation activities also continued to develop; much of the progress due to the efforts of our preservation consultant. A modest increase in staff combined with some new equipment and internal space changes have combined to produce a more effective and responsive service. This is an important first step that, along with the appointment of a Preservation and Collections Librarian, will lead to a greatly strengthened preservation program.

#### Administration and Personnel

The past year saw the implementation of a major effort to improve the salaries of librarians and support staff who are in the lower quartiles of their respective ranges. The project received strong support from the Provost and resulted in significant improvement in MIT's position among its peer institutions.

The transfer of responsibility for the physical delivery system to Administrative Services was effected with a visible improvement in the speed and quality of service. The efficiency of this service is closely linked to the Libraries short- and long-term storage plans, especially as it involves the movement of material to and from the RetroSpective Collection. Improvements continued to be made, as well, in the internal accounting and commitment systems especially with regard to currency of information; the beneficiaries of these improvements are those responsible for the budgets of the several departments and services in the Libraries.

During the 1986 Independent Activities Period, members of the Libraries' staff conducted a number of activities ranging from online information sources to the history of navigation, and from scholarship on women to thesis preparation. The Libraries arranged for a presentation by a staff member from the Cambridge Public Library on its collections and services.

This year marked the conclusion of 25 years of service to the MIT by Mary Louise Daly who retired on June 30. Mary Louise Daly was known to several generations of MIT faculty and students as the source of information and reference service during evenings and weekends in both the Science and Humanities Libraries. Her unfailing good humor and her devotion to the Institute and the Libraries will be missed by all of her colleagues.

#### Space

While no firm decision was reached regarding the future of the Rotch Library, a great deal of effort was expended in connection with that matter during the year. The Director of Libraries and the Rotch Librarian participated extensively in a committee that included the Dean of the School of Architecture and Planning and the heads of the two departments in the School. This group investigated a series of options and developed a number of alternatives for various sites and building renovations. The firm commitment of the Institute administration to the solution of this problem remains and there is considerable optimism that a final and lasting solution will shortly be forthcoming. The decision to improve the airflow in Hayden basement will mean that plans can now go forward for a number of internal space changes in that building. Approval was also received for the air conditioning of Rotch Visual Collections. During the year, a decision was made to withdraw from the New England Deposit Library (NEDL) and to transfer some of the collections presently there to the new Harvard Depository in Southborough, Massachusetts.

Several internal space programs were undertaken including a large-scale project to repair and seal all the windows in Hayden Library. A study of the environmental conditions in the Hayden basement recommended a major upgrading of those facilities. The recommendations, including the installation of temperature and humidity controls in the Rare Book Room, were approved and work will begin in FY87. In the MIT Museum, a second major renovation took place that will result in several new galleries, improved work and storage space, and the creation of two new classrooms. Space in general, and especially working space for staff continues, however, to be one of the most pressing problems in the Libraries.

### Microreproduction Laboratory

Following a decision made last year, six Infortext card systems were purchased to be attached to copiers in the divisional libraries so that a more convenient means of charging for quick copies could be offered. During the year it was determined that it would not be possible to attach these units to the existing Xerox 3100 machines and replacements for them were sought. As has been true in the past, it remains extremely difficult to find copiers suited to the needs of libraries both in terms of protection of the collections and durability of the equipment. This issue is expected to be resolved early in the 1987 academic year.

Among the other activities in the Laboratory were a number of microfiche filming projects for the Libraries and for several MIT departments; initiation of a project to upgrade the storage and maintenance of archival film masters of MIT theses; an increase in the volume of requests for MIT theses from Japan and China; the extension in the use of microcomputers for internal management and accounting; and the development of a microcomputer-linked Computer Assisted Retrieval (CAR) system. With regard to the last item, the Microreproduction Laboratory has been working with the Minolta Corporation to produce a low cost CAR system using the Minolta 505 reader-printer and an IBM PC/XT microcomputer. Using software developed in MRL, the system is available for demonstration to the Institute community.

### MIT Museum and Historical Collections

In addition to the major renovation mentioned above under "Space" the Museum continued to consolidate and reorganize its facilities in buildings N51 and N52. For the first time, the Museum's collections are housed in air conditioned space. Although the equipment is somewhat antiquated, its use has created a vast improvement over the previous storage environment and the central photographic files, architectural drawings, and Hart Nautical Collections are considerably better protected. The Museum Shop has grown remarkably, with an almost three-fold increase in sales volume over the previous year. With major funding from Raytheon, a video tape was produced on the history and technological impact of the subminiature vacuum tube. This tape will be distributed without charge to appropriate repositories. Significant progress has been made in development of a reproduction policy for the valuable plans in the Hart Nautical Collections where, in addition, work has begun on the organization of the Bethlehem Shipbuilding Collection.

In terms of exhibits, the past year was highlighted by a series of exhibits of great photographers that includes the work of Berenice Abbott, Minor White, Ansel Adams, and Yulla (Lipchitz). The traveling exhibition, "Nihonga: Contemporary Japanese Painting in the Traditional Style", sponsored by Kyocera and Wacoal Corporation was one of four exhibits in Compton Gallery, the others being "Expanded Vision: Bill Parker '74" (plasma sculptures), "Piece by Piece - The Architecture of Renzo Piano", and "Yulla - Images of Infinity".

The Institute, through the Museum, formally acquired James Ossi's "Bubble Machine" that is permanently displayed in the Building 6 lobby; a major gift from the David Bermant Foundation made this acquisition possible. Educational programs included tours, lectures, and special programs offered through the Peabody School in Cambridge, the Cambridge School Volunteers, and the Mario Umana Harbor School of Science and Technology.

### Institute Archives and Special Collections

Along with the Institute's own 125th anniversary, the past year witnessed three other celebrations in the Department of Humanities, the Department of Urban Studies and Planning, and the Department of Materials Science and Engineering. All of these drew heavily upon archival collections as did other Institute staff working on reports on graduate housing, minority student recruitment, and development.

Scholarly publications by Institute and outside researchers continued to promote a national and international awareness of the unique and rich holdings in the Institute Archives and Special Collections. Researchers used the records of the Office of the President from the Compton/Killian period as a central source to write about nuclear physics before and after World War II as well as about the Servomechanisms Laboratory, operations research, the Radiation Laboratory, attitudes toward the G.I. bill, and the Finnish architect, Alvar Aalto. Compton's presidential files were a major source for one book on the politics of science and for another on Vannevar Bush and the differential analyzer. Records from archival and manuscript collections provided information on subjects as diverse as the origins of the discipline of art history, U.S. foreign policy, the Orville Wright Flyer, NASA and American universities in the 1960's, the history of precision engineering, the debate over the SST, and "the artistic and literary proclivities of scientists and engineers."

Major collections were processed during the year through the support of grants. The papers of William Seifert, civil engineer, and the records of the Neurosciences Research Program were completed under the Title II-C program. Work on the Roman Jakobson Collection, supported by the National Endowment for the Humanities continued with completion expected by the beginning of the fall semester.

### Gifts

Two significant collections of books were received during the year. Gian-Carlo Rota, Professor of Applied Mathematics and Philosophy, donated a large collection in mathematics. A substantial collection of Russian language scientific and technical material from the library of Ronald Paul Remorenko was given by his widow. Major gifts were also received from Harfax Database and the Nuclear Regulatory Commission.

The files of Julius A. Stratton, President-Emeritus, were formally transferred to the Archives as were the papers of Vincent A. Fulmer who retired as Secretary of the Institute. The Francis Bitter National Magnet Laboratory made the first transfer of records from its offices to the Archives. Among the other collections received were the papers of Harold Isaacs, important in the area of ethnicity, and Mel Horwitch, whose research includes a major study of the supersonic transport. From Robert Heinmiller, the Archives received the records of POLYMODE that complement the MODE records on ocean currents donated several years ago. The collections of Roman Jakobson, Louis Menand, Ithiel de Sola Pool, Walter Rosenblith, and Jerome Wiesner were strengthened through the deposit of additional material. Among gifts to the MIT Museum were photographs from the Creative Photography Laboratory and the Visible Language Workshop, and instruments from the Laboratory for Nuclear Science.

### Books, Computers and Libraries

This report began with some remarks on a series of significant events that occurred in the MIT Libraries during the past year. The events involved books, the application of technology to libraries, people, and the relations among all of these. While there has been tremendous excitement in the MIT Libraries about the impact of automation and the tremendous potential this has for the improvement and expansion of services, it is important that those involved in research libraries not lose sight of the importance of the printed word. There is a vast wealth of recorded information in the MIT Libraries, much of it constantly in use by students, faculty, and staff, but much of it waiting to be called upon as the basis for future scholarly endeavor. While by no means an exhaustive list, the following are among some of the collections that symbolize the great and enduring strength of this library:

- the monographic collections in engineering and technology that are among the largest held by ARL university libraries; there are exceptionally strong serials collections in the same areas as well;
- the Vail Collection with its unique holdings in 16th and 17th century electricity and magnetism and the early history of aeronautics;
- the linguistics collection, historically outstanding, and recently greatly strengthened by the addition of the Roman Jakobson Collection;
- the Hart Nautical Collections including the Forbes whaling prints and the Herreshoff collection of yacht designs that complement the outstanding collections in naval architecture and marine engineering;
- the architectural folio collection in Rotch Library, assembled in the late 19th and early 20th centuries as part of the teaching collections and now a national resource for the study of the history of architecture;
- the records of the Office of the MIT President that not only document the past of a great educational institution but are equally important for the history of science, technology and society;
- the labor economics holdings in the Industrial Relations Collection, considered to be one of the five best collections in the United States;
- the collections of NASA publications complemented by an exhaustive collection of books and serials in aeronautics and astronautics.

The commonality of the collections listed above is not that they belong to one research library but that they are irreplaceable resources for the documentation of the past and for the construction of the future. That, after all, is what libraries are really all about.

The following statement appeared in an exhibit commemorating the two millionth volume acquisition and the 125th anniversary of MIT:

"The MIT Libraries' acquisition of its 2,000,000th printed volume, while a significant achievement in itself, should be viewed in the context of the development of collections and services over the entire history of this institution. While the number of books in a library clearly says something about its capacity to respond to the information needs of its users, there are many other



collections in a variety of forms and many types of service, and, perhaps most important of all, a library staff that are essential to the fulfillment of the library's role in the educational process. At this significant time in the history of the MIT Libraries, I would like to recognize the great contribution that has been made over the years by those who select, organize and service the collections that presently number more than 5,000,000 items.

The MIT Libraries are presently engaged in a major effort to incorporate the best of 20th century technology into such activities as circulation, cataloguing, information storage, bibliographic searching, and access to external sources of information. In the years immediately ahead we can expect to see further applications of compact discs, local area networks, and large scale computer storage that will enable the MIT Libraries to extend its capacity to serve as a major force in the teaching and research programs of the Institute.

The above notwithstanding, the book is still the symbol and the heart of any research library. We are pleased during this year that is the 125th anniversary of MIT (and its libraries), that saw the formal opening of the Barton online system, and the occasion of the acquisition of the 2,000,000th volume, to reaffirm our strong conviction that books are here to stay."

JAY K. LUCKER

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## Lincoln Laboratory

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Lincoln Laboratory is operated by MIT as a Federal Contract Research Center for performing research and development in advanced electronics. During the past year, agencies of the Department of Defense (DoD) -- the Air Force, Army, Navy, and the Defense Advanced Research Projects Agency (DARPA) -- supplied 95.6 percent of the Laboratory's budgetary support. The Federal Aviation Administration provided most of the non-DoD support. In fiscal year 1986 the operating budget was \$362 million, supporting the efforts of 840 professional staff, 81 percent of whom hold advanced degrees.

During the Fall the MIT Lincoln Laboratory Advisory Board was established by the President of MIT to advise the MIT Administration on the quality of Lincoln Laboratory programs and on other matters relating to the Laboratory that may be of interest to the Administration, and to advise the Laboratory on new research directions and national research needs. Norman R. Augustine, Senior Vice President, Martin Marietta Corporation, was appointed Chairman of the Advisory Board. The Board reports to the Provost of MIT. Two meetings were held during the year.

Two administrative changes at the Laboratory Steering Committee level occurred during the year. Philip Waldron was appointed Personnel Manager and Dr. Charles F. Bruce was appointed Associate Head of the Engineering Division to succeed Mr. Waldron.

Technical work areas at the Laboratory include: radar and optical sensors, measurements, and systems; satellite communications; signal design and processing; lasers; solid-state devices; digital technology, circuitry, and data systems; machine intelligence; tactical and strategic systems and countermeasures; and air traffic control systems. Unclassified highlights of several accomplishments during the past year are summarized below.

### KWAJALEIN INSTRUMENTATION FOR FIELD EXPERIMENTS

Since 1962, the Laboratory has operated the Kiernan Re-entry Measurements Site (KREMS) instrumentation at the Kwajalein Atoll and provided technical support for the associated field test planning and radar engineering. The KREMS instrumentation consists of a radiometer and four radars: ALTAIR at the VHF and UHF bands, TRADEX at L- and S-bands; ALCOR at C-band; and the Millimeter Wavelength Instrumentation Radar (MMWIR) at K<sub>a</sub>- and W-bands. These combined sensors have a frequency span of 155 MHz to 97.3 GHz. The high sensitivity of the sensors and the variety of waveforms available for use on each provide a rich spectrum of target tracking and data collection capabilities. The KREMS instrumentation can be employed effectively in a variety of field measurements and experiments, including the observation of space and missile system objects and re-entry physics phenomena.

The KREMS support of field experiments in re-entry physics has resulted in the development of body-discrimination techniques important to the ballistic missile defense problem posed for terminal defense systems. For several years, measurements were made to develop and test algorithms for discriminating re-entry vehicles with substantial payload capacity from decoys and other spurious bodies during atmospheric re-entry. This effort included examination of the behavior of ionized wakes and plasma sheathing effects on electromagnetic scattering.

The MMWIR is a recent addition to the KREMS instrumentation which has been operating since 1983. The MMWIR consists of a high-power, coherent radar with a high range resolution and a sensitive radiometer. Active and passive signature data are being collected for development of object identification and discrimination techniques. In addition, the radar serves as a test bed for radar system technology and discrimination engineering development.

During the past year, a project was initiated to design, procure, and install equipment and software at Kwajalein for real-time data processing of the 35 GHz channels of the MMWIR at very high data rates. The objective of this effort is to establish a facility where body identification and discrimination techniques can be evaluated in real-time during field tests. Previously, emphasis has been concentrated upon post-mission analysis of the radar signatures to ascertain the size, shape, scattering configuration, and motion of a body about its center of mass.

### SATELLITE COMMUNICATIONS

Lincoln Laboratory is nearing the culmination of a major, multi-year effort to help develop the next-generation military satellite communication (MILSATCOM) system. Over the past decade, the profusion of space communications technology has affected the military community probably even more than the rest of society. Commanders have grown accustomed to their relatively new capability of being in instant worldwide touch with thousands of planes, ships, and mobile units equipped with small MILSATCOM earth terminals. The

problem is that these links are presently vulnerable to hostile electronic interference which might render them useless during a conflict.

In 1978, Lincoln began working on a new MILSATCOM concept for mobile terminals which promised to be almost impervious to such "jamming". The main ingredients of the concept were: a move to the extremely high frequency (EHF) radio band, advanced spread spectrum modulation, on-board digital signal processing, and an autonomous space-based switchboard function for establishing links dynamically.

By 1982, this system concept and its underlying technologies had been demonstrated in the laboratory. On that basis, the nation began building a large new MILSATCOM system called MILSTAR. This system is slated for operation in the 1990s and beyond. Lincoln was asked to build two precursor payloads for early launch to provide sufficient operational test capability that thorough end-to-end systems tests employing industry-built earth terminals could be carried out prior to the deployment of MILSTAR. These advanced payloads are to be carried on two of the FLEETSAT series of MILSATCOM spacecraft and are called the FLEETSAT EHF Packages, or FEPs.

Developing the FEPs and their associated ground control facilities has been one of the major efforts of the Laboratory for the past four years. The first FEP payload was recently delivered for integration into its host satellite and will be launched within the next few months; the second FEP will follow before the end of 1987. These packages will represent a major step forward in MILSATCOM technology.

#### SPACE RADAR TECHNOLOGY

A multi-year program of radar system studies and associated technology development has been initiated at the Laboratory under Air Force sponsorship to define, develop, and test critical technology associated with a space-based radar concept for worldwide air and surface surveillance. Although there has been considerable interest for a number of years in a space-based radar capability, previous concepts posed excessive levels of technical risk and cost.

To compensate for motion of the radar platform, the space-based radar concept proposed by the Laboratory employs a phased array antenna operating in a displaced phase center antenna mode. This technique was employed in an airborne experimental system developed at the Laboratory under the Multiple Antenna Surveillance Radar (MASR) program in the mid-1970s. The concept employs adaptive techniques to cancel the distributed doppler spectrum of the mainbeam clutter returns and allows for detection of moving bodies down to very low velocities. The radar will use low-sidelobe phased arrays and on-board signal processing to null sidelobe jammers adaptively and cancel mainbeam clutter. Recently the scope of this program has been broadened to include system and technology areas of general interest to space-based radar such as detection of low radar cross section targets, advanced signal processing techniques and hardware, and high performance phased array component development.

To date, the program has emphasized concept validation through extensive mathematical analyses, computer simulation, and component testing. Component design and integration has led to the assembly of antenna and signal processor test beds. Clutter cancellation and jammer rejection capabilities have been measured in a specially constructed ground test facility in a continuing cycle of enhanced subsystem integration for increasingly realistic proof of concept demonstrations. In parallel, technology for space-compatible transceiver modules and other electronic components is being developed and tested.

#### SATELLITE SURVEILLANCE

##### Signal and Data Processing

Narrowband, high precision radars represent an important resource for high altitude space surveillance. Tracking of high-altitude satellites poses a unique problem of low single-pulse signal-to-noise ratio. Processing of many seconds of radar data is needed to detect and track such objects. The problem is aggravated by the changing attitude of the object, causing aspect angle variations and resulting in a complex signal structure.

The combined problems of low signal-to-noise ratio and complex signal structure has led to the development and implementation of sophisticated real-time signal processing algorithms. Commercial floating-point array processors have been used to provide the necessary throughput in numerical calculations. These techniques have been successfully demonstrated during two years of successful operation.

High precision metric data on the satellites are obtained by the use of these processors. Translation of high-precision to high accuracy in metric data demands improvements in modeling of perturbations of satellites due to the geopotential, external gravitational sources, atmospheric drag, and radiation pressure. Initial results include the verification of the existence of atmospheric drag at high altitudes (over 2000 km), comparison and validation of new low-altitude atmospheric drag models, and the establishment and monitoring of a historical calibration data base on all of the sensors of the deep-space surveillance system. A broad development effort is underway in all of these areas.

## Command and Control

Lincoln Laboratory has been instrumental in the development and deployment of a deep-space surveillance network, including both optical and radar sensors. Recently, efforts have been focussed on techniques for the optimal allocation of these resources to the missions of space object catalog maintenance, tracking of newly-launched satellites, and status monitoring. The concepts and algorithms for a new prototype deep space network control processor have now been tested successfully in a real-time operational environment. The efficacy of the algorithms was tested using several newly-developed network performance measures. The improvement in the performance of the network proved to be equivalent to that of an additional high-throughput radar in the system.

Follow-on work in this area includes extension of the algorithms to incorporate low-altitude as well as deep-space satellite observations into the system and the development of machine intelligence concepts applicable to space surveillance.

## OPTICAL ATMOSPHERIC COMPENSATION TECHNOLOGY

The optical atmospheric compensation program is aimed at developing techniques for improving the efficiency of the propagation of optical signals from ground to space. As noted in a previous report on this subject (in 1982), the integration and testing in the laboratory of an adaptive optical system was carried out in order to characterize system performance in a simulated atmospheric environment. The system performance was reported to be better than the projected goals for this 69-channel system.

In late 1982 this atmospheric compensation system was shipped to Hawaii to be installed on the 60-cm telescope at the DARPA Maui Optical Site for testing under realistic atmospheric conditions. Initial experiments in propagating to a ground-based station were followed by tests to an aircraft flying at three km above the site. In both series of experiments the system performance was found to agree well with theoretical predictions.

In late 1985 the final series of tests, involving propagation to instrumented sounding rockets, was conducted. The objective of compensating a collimated beam propagating through the entire atmosphere was met. There is now a follow-on program in which the experimental system is being upgraded to 241 channels and to state-of-the-art components, for tests in 1987-88.

Although these experiments are directed primarily to the application of laser propagation, the technology applies to astronomical imaging as well. At the conclusion of this program, the capability will exist for approximately one-meter-scale adaptive optical systems to compensate atmospheric distortion.

## COHERENT ADDITION OF LASER BEAMS

A novel technique has been developed for combining laser beams coherently using binary gratings. Coherent addition of laser beams requires an efficient beam adder, operation of each of the laser sources in a particular phase state that depends on the number of laser sources, and an optical feedback mechanism to maintain the laser array in the required relative phase state. These requirements can be satisfied simultaneously with holographic binary gratings.

The approach uses a specially designed diffraction grating which, if illuminated with a single beam, produces N parallel beams of equal magnitude and correct relative phases. With this technique the coherently-summed beams maintain the beam profile characteristics of a single laser beam and no far-field sidelobes are produced. Efficiency of addition can be over 95 percent. Coherent addition experiments were performed with monolithic linear GaAlAs laser arrays and arrays of discrete HeNe and CO<sub>2</sub> lasers.

This technique has several potential applications. For example, hundreds of low power diode lasers in two-dimensional arrays might be used in place of a single high power laser for communication, radar imaging, doppler spectral measurements, annealing, and spectroscopy.

A key advantage of combining laser beams rather than building the beams in serial fashion through amplifier stages lies in avoiding the progressive difficulty of isolating amplifier stages from parasitic oscillations. In addition, in an amplifier chain if any of the laser elements fails the entire system fails. When adding many low-power lasers, however, the degradation of the system due to single element failure is graceful.

The ability to combine beams coherently from multiple lasers can also allow the control of gas, solid state, and dye lasers by a low-powered laser or modulator. Thus, a high-powered laser beam could be modulated with FM and chirp signals for long distance communications and radar imaging.

## INFRARED AIRBORNE RADAR

The purpose of the infrared airborne radar program is to develop technology which utilizes coherent carbon dioxide laser imaging radars, both pulsed and cw, for ground observation under day, night or poor

visibility conditions. A transportable ranging (pulsed) radar with six-meter accuracy was developed several years ago to demonstrate component technology and to test image concepts. This system has been upgraded to provide higher range and doppler (velocity) measurement accuracy and resolution, and registered thermal imaging capabilities. All data are recorded directly on computer-compatible tapes for off-line processing.

An airborne version of this basic optical radar was built and is currently being used to collect data on targets and backgrounds. The airborne system features a very wide (20 degrees) field of view search mode; and a high frame rate, narrow field-of-view raster scan mode. The radar has demonstrated a six-meter range accuracy in the pulsed mode, and a one-mile/hour velocity detection capability when operated in the cw mode. Measurements made with this sensor provide signature data and the opportunity to test various detection and classification procedures over a wide variety of background terrains.

An additional goal of this program is to exploit the various forms of imaging (intensity, range, velocity, thermal, and visible) available from this multidimensional sensor for automatic detection and classification of objects within the field of view.

#### ADVANCED AIRBORNE RADAR PROCESSOR TECHNOLOGY

In netted radar program demonstrations at Fort Sill in 1981, Lincoln Laboratory showed that coherent radars operating with modern high-speed programmable signal and data processors could provide a high quality, comprehensive, real-time picture of moving military vehicles on the battlefield. The ground-based radar's view of the battlefield was limited by the terrain; however, the airborne radar, when flying over or near the area of interest, had steep lookdown angles and thus excellent visibility.

Small airborne remotely piloted vehicles (RPVs) are very attractive platforms for such an airborne surveillance radar. The challenge is that these small vehicles have very limited volume, payload weight, and electrical power. Lincoln is testing a combined radar and signal/data processor which is compact enough to fit into a small RPV.

The signal/data processor is the key element of the system. Its multiprocessor architecture features a combination of commercial single-board computers based on the 68000 processor together with custom designed multilayer boards with two complex custom VLSI (three-micron NMOS) processing chips for high-speed signal processing. This portion of the processor is capable of 100 million real operations per second and is used to convert the 25 million bits per second of raw radar data into moving target detections that can be passed to the ground via the 20 kilobit per second data link. The processor weighs less than 50 pounds and has a volume of about one cubic foot.

This processor will also be used by an Army laboratory in a technology demonstration of a small ground-based battlefield radar. The programmability, capacity, and speed of this processor will permit it to be used to support a variety of challenging future sensor system applications.

#### WAFER-SCALE VLSI INTEGRATION USING LASER LINKING

Techniques for restructuring the interconnect links on a silicon wafer for defect avoidance and customization have been described in previous reports. The linking technology employed in these first designs used a vertical microweld between two levels of metal interconnect separated by an amorphous silicon dielectric sandwich. In order to expedite the transfer of this technology to industry, a new link structure has been developed which requires no extra processing steps and can be fabricated in any standard MOS process sequence. The new device uses two diffusions of either n- or p-type separated by the minimum gap defined by design rules. In the unprogrammed state the impedance between the metal contacts to these diffusions is that of two series-opposed diodes. Upon illumination by a laser pulse of a millisecond duration and a power level of a few watts, the dopant is redistributed across the gap leading to a connection in the range of 100 ohms. Many thousands of such links have now been programmed successfully with excellent repeatability over a wide range of laser power. It is now possible for designers to begin designing and fabricating very large area circuits using this laser link to implement redundancy and post-fabrication customization using conventional fabrication facilities.

In order to demonstrate this new linking technology, a wafer-scale design is being fabricated in the MOSIS foundry which will perform the dynamic time warping function for speech recognition. This is the computationally intensive algorithm which performs a time-aligned matching operation to compensate for temporal variations in the incoming speech for comparison with templates stored in a reference library. The complete system is expected to provide a capability for real-time connected word recognition using a 4000-word vocabulary.

As a further demonstration of the laser linking customization capability, two new wafer-scale systems have been simulated using a wafer-scale multiply-accumulator array previously designed to implement a fast Fourier transform. One design implements a Hough transform used to fit clusters of image data points to the straight line representation, a common function in image processing. The second design provides a dynamically programmable 13X13-pixel, two-dimensional convolver for performing edge detection, filtering,

and other neighborhood-oriented image processing functions. These two new wafer-scale systems will be physically restructured and connected to general purpose image processing hardware to provide a significant increase in throughput for development of experimental image processing algorithms.

#### RADIATION-HARDENED ELECTRONICS

Integrated circuits for spacecraft applications must resist degradation produced by radiation that is naturally present in the space environment or that may be generated artificially. Significant progress has been made at Lincoln toward developing radiation-hardened integrated circuits fabricated in silicon-on-insulator (SOI) films. Such circuits are inherently less sensitive than bulk silicon circuits to ionizing radiation because SOI devices have a much smaller active volume for generating radiation-induced charge. In addition, because the SOI structure permits complete device isolation and reduces parasitic capacitance, SOI circuits can have higher packing density and higher speed than equivalent bulk silicon circuits.

Device-quality, nearly single-crystal SOI films have been prepared by zone melting of polycrystalline silicon layers deposited on oxide-coated silicon substrates. Complementary metal-oxide-semiconductor field-effect transistors (MOSFETs) and junction field-effect transistors (JFETs) have been fabricated in such recrystallized SOI films. During irradiation of these devices, a negative bias is applied to the silicon substrate to minimize the trapping of radiation-induced charge in the buried oxide layer beneath the silicon film; such trapping limits the radiation hardness of silicon-on-sapphire devices. Hardness to a total dose of  $10^7$  rad has been achieved for the SOI MOSFETs; at higher radiation levels these are eventually degraded by charge trapping in the gate oxide. The JFETs, which do not utilize a gate oxide, have exhibited radiation hardness up to  $10^8$  rad, a record for silicon devices.

The feasibility of utilizing zone-melting-recrystallized SOI films for integrated circuits has been demonstrated by fabricating fully functional 1K static random-access memories and 1.2K gate arrays, which are superior in speed performance to similar circuits fabricated in bulk silicon. The memories have exhibited state-of-the-art transient radiation hardness, with no change in memory state up to  $10^{11}$  rad/s.

To date, the development of SOI technology has been focused primarily on radiation-hardened electronics for use in space. Ultimately, this technology could also have an important impact on commercial VLSI circuits, including the realization of three-dimensional integration.

#### CHARGE-COUPLED SIGNAL PROCESSING DEVICES

Despite the continued advancement of high-speed digital technology, there exists an orders-of-magnitude gap between the signal processing requirements of many types of advanced electronic systems and the projected digital circuit capabilities. The Laboratory's continued effort in charge-coupled signal-processing devices is based on the fact that these analog devices can be designed to perform wide-bandwidth front-end processing very efficiently, thereby greatly reducing the demands on any subsequent analog-to-digital conversion, data transfer, and digital computation.

As an example, a spread-spectrum communication receiver generally contains a programmable matched filter which must reject interference and recover the transmitted data. A charge-coupled device was recently developed which operates as a dual-channel, 128-tap filter and performs correlation of the signal against a binary reference at sample rates greater than 40 Ms/s with over 40 dB of dynamic range. On-chip digital logic and driver circuits permit rapid filter programming in only 100 ns. The integrated device provides the equivalent of  $10^{10}$  operations per second with less than one-watt power dissipation. All-digital correlators capable of the same function are being developed elsewhere, but even with a three-fold reduction in feature size these devices require more than an order of magnitude of more active silicon area and power than the charge-coupled correlator. Because of this substantial advantage, the charge-coupled correlator technology is being actively transferred to industry, with applications envisioned in communication and radar systems.

In addition to the correlator described above, the Laboratory is investigating other analog charge-coupled devices. These include matrix-matrix product, discrete-Fourier-transform, and analog-buffer-memory structures for signal processing at up to 100 Ms/s sample rates with 50 dB of dynamic range. Research to extend the technology substantially is underway. In particular, the use of focused-ion-beam implantation to produce a transfer-aiding longitudinal electric field under each electrode is being explored, with the goal of achieving sampling rates beyond 250 Ms/s. Unique circuit architectures which integrate charge-coupled structures with long-term analog memory cells (previously invented at the Laboratory) are being developed for on-focal-plane image processing and artificial adaptive neural networks. Through this effort, charge-coupled devices should bring further capability not only to conventional signal processors, but also to autonomous robotic systems.

#### NEURAL NETWORK MODELING

A neural network model has been developed for exploring the applicability of such networks to speech

recognition systems, particularly for performing elemental phonetic distinctions such as vowel and consonant discrimination. The model (based on early work by John Hopfield) consists of a densely interconnected array of 120 simple elements, each element receiving appropriately weighted information from all other elements. The weights are developed during the training process when the network learns the information which it is expected to recognize. In early experiments the network has been shown to function as an associative memory, with the capability of retrieving one out of a stored family of eight vowels when presented with an appropriate input stimulus. Additionally, the model can recognize familiar vowel spectra and can discriminate between initial consonants in an acoustically-corrupted rhymed-word pair.

Several experiments have been conducted to assess the potential of the neural network model. In one experiment, half of the information characterizing each of eight stored states was specified, and the network recalled the correct response 51 of 64 times. Of the 13 incorrect responses, most were spurious states which were very close to the correct response.

In another experiment, monosyllabic words were scanned and spectral cross-section representations were applied to the network every ten milliseconds. That portion of the word containing a vowel corresponding to a stored state was usually correctly recognized.

Emulation of the diagnostic rhyme test, which is commonly used as an objective intelligibility measure for rating speech processing systems such as vocoders, was also attempted. In the test, a human listener (or neural network model) must choose between two initial consonants in monosyllabic word pairs (e.g., pool vs. tool) which generally differ in only a single acoustic feature. In preliminary tests, the model was observed to approximate the performance of human listeners.

Recently the Laboratory has begun to explore the utility of theories on how a human brain manipulates sensory information through the use of massively parallel (neural) networks to accomplish image recognition. This architecture may provide a self-teaching machine with applicability to the solution of a wide variety of detection and recognition problems.

#### WEATHER RADAR

Severe weather, especially the turbulence and low-altitude wind shear associated with thunderstorms, is a significant hazard to both en-route and terminal aircraft operations. Under sponsorship of the Federal Aviation Administration, the Laboratory is developing techniques for using doppler weather radars to determine the location and severity of hazardous weather phenomena and to provide timely information to air traffic controllers and pilots.

In a program jointly undertaken by the National Weather Service, the Air Weather Service, and the Federal Aviation Administration, a "next-generation doppler weather radar" (NEXRAD) is being developed and a nationwide network of these radars will be installed. In order to make the output of these radars useful in the en-route air traffic control process, a continuously operating, real-time processing system is required to translate the radar returns into information on the location and severity of the turbulence and precipitation associated with thunderstorms, and to display this information in a form easily interpretable by the air traffic controller and/or pilot.

In addition to this national network, the FAA plans to install NEXRAD-like terminal doppler weather radars at a number of major air terminals to provide information to the terminal controllers on low-altitude weather phenomena in the vicinity of the airport. These radars focus on the detection and characterization of low-altitude wind shear associated with thunderstorm-induced microbursts. As in the case of en-route weather observations, it is necessary to develop techniques for automated weather data processing and interpretation to avoid the need for a trained meteorologist to be continuously on duty to interpret each radar report. Among the principal technical issues are the separation of the radar return due to low-altitude weather phenomena from that caused by radar ground clutter, and the characterization of weather phenomena based on radar observations of returned signal intensity, doppler shift, and doppler spread.

The Laboratory program includes the operation of two doppler weather radars, as well as instrumented aircraft (for comparison of aircraft-encountered turbulence and wind shear with radar estimates), and a network of 30 surface weather stations (for surface wind shear verification). At the end of the participation in a major microburst experiment in Huntsville, Alabama, during 1986, the equipment will be moved to Denver, Colorado, for a more operationally-oriented test in the 1987-1988 time period of the detection algorithms and related controller display products developed at Lincoln.

W.E. MORROW, JR.

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## Project Athena

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Project Athena is an exploration of the potential uses of high performance, networked graphics workstations in the MIT curriculum. Supported by major grants of hardware, software, maintenance and technical staff from Digital Equipment Corporation and IBM, Athena is fostering innovative educational applications of computing throughout the Institute.

Most of the work during the past year at the Project can be divided into three distinct areas:

1. Encouraging, supporting and understanding the effects of faculty-based efforts in innovative uses of computing.
2. Developing a base of software running on heterogeneous hardware that provides a windowed, graphics environment, file service, mail service, print service and distributed authentication and system management.
3. Installing and operating a large scale base of hardware so that new curriculum ideas can be tried and tested.

Activities in each of these areas are described in sections below.

### INNOVATION IN THE CURRICULUM

Each semester Project Athena solicits proposals from the faculty (as well as from student groups with faculty advisors) for innovative uses of computing. After these proposals are reviewed by faculty/student committees, the most worthwhile are funded.

To date, Athena has funded 93 projects spanning all the schools and most of the academic departments. Funding for these projects has been raised from a range of sponsors as part of MIT's overall \$20 million commitment to Athena. So far, \$4.024 million has been provided for curriculum development.

Virtually all the curriculum development projects use computing to extend conventional teaching methods rather than replace them. Typical uses of computing include:

- numerical simulations of systems too complex for analytic solution;
- use of computerized data acquisition in laboratories;
- use of video projection in lectures to show complicated vector fields or to illustrate (via animation) dynamic processes;
- exercises that engage in a natural-style dialog in foreign languages;
- design tools that allow students to explore a broader range of design options than pencil-and-paper methods allow.

This past year, a staff of professional applications programmers was formed to provide assistance to the larger faculty-based projects. This staff works directly with selected projects and develops software tools of use to a number of efforts.

The Project Athena Study Group, a faculty committee appointed by the Provost, has initiated a set of case studies to explore the effects of selected curriculum development projects on students and faculty. These case studies include in-depth interviews and formal surveys. Reports derived from these studies are expected to be available by the Spring, 1987 semester.

Over the course of the next two years, we expect many of the curriculum development efforts to continue and plan to foster the emergence of new ideas. One area of particular interest is one or more projects targeted towards freshman year subjects.



## BUILDING A COHERENT COMPUTING ENVIRONMENT

In the past year, a significant portion of the Athena staff has been involved in creating the base of software needed to support an integrated network of high performance graphics workstations from Digital and IBM. The major pieces of the system include:

- a "window manager" that allows regions of a large format graphics display to be used for different purposes concurrently. This software, called X, is already working on at least four different manufacturers' hardware and may well become a *de facto* standard for workstation window systems. X has already been adopted as a product by one vendor. Further enhancements of X during the coming year should solidify this leading position.
- enhancement of a system developed at the Laboratory for Computer Science called Remote Virtual Disk that provides for access of files across the campus network. This system allows sharing of software libraries by a large number of workstations, avoiding the need for storing and maintaining thousands of local copies. We also intend to use this system for storing subject-related information and private storage for faculty and students.
- development of Kerberos, a network-based authentication server that allows various network-provided services to verify the identity of authorized users.

## INSTALLATION AND OPERATION

Project Athena has passed through two distinct phases of development. In the first phase, the available "off-the-shelf" computer hardware was installed to provide faculty and students with a working computing environment for early experimentation. In the second phase, high performance, graphics workstations are being installed along with software that provides a relatively high level of coherence across different hardware types.

Athena is in the transition period between these two phases. The first wave of workstations is being installed, and plans for conversion of the ten existing Athena computing facilities are being developed.

Work is now underway to place Athena equipment in five MIT living groups. This is the pilot phase of a planned expansion of Athena into most, if not all, living groups. As part of this pilot phase, the Project Athena Study Group is sponsoring a study of how living groups are affected by the availability of high performance computing.

By June, 1988 we anticipate completing the installation of approximately 1,500 workstations, all linked to an array of services delivered over the MIT campus-network. The Athena system will extend into laboratories, libraries, living groups, department areas, classrooms, offices and public work areas.

STEVEN R. LERMAN

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# Associate Provost and Vice President for Research

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## Francis Bitter National Magnet Laboratory

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The Francis Bitter National Magnet Laboratory, with support from the National Science Foundation, operates a high magnetic field facility available, free of charge, to qualified scientists throughout the country. The Laboratory also designs and builds magnets, and performs research in condensed matter physics, condensed matter chemistry, and biophysics.

Highlights of the User Program for the past year include:

1.) Hybrid Magnet. A record high dc magnetic field of 33.6 tesla was produced in the Laboratory's hybrid magnet when the central field was enhanced by a 3.5 T contribution from holmium pole pieces.

2.) Pulsed Field Facility. A record field of 68.4 tesla was generated using a new metal-matrix microcomposite Nb/Cu in a practical pulsed field magnet. The magnet is a wire-wound multilayer coil that is cooled to liquid nitrogen temperatures and contained in a precompressed hardened steel structure. This development indicates that one can make long pulses at very high fields and suggests that these materials will be useful for both dc and pulsed field magnets.

3.) Exotic Superconductors. Several remarkable superconducting systems have recently been discovered. A number have been studied at the Laboratory, including heavy Fermion superconductors, magnetic superconductors, and organic superconductors. Much of this work requires the unique combination of high fields and low temperatures that NML provides.

4.) Continuing Studies of 2D Electron Dynamics. About ten groups regularly use the high fields at NML to study electron dynamics in two-dimensional semiconductor structures. This topic is now the second most active (after superconductivity) at the Laboratory. Systems studied include: GaAs/(GaAl)As, Si MOSFET's, InAs/GaSb, graphite, HgTe/CdTe, and InGaAs/GaAs.

### SUPERCONDUCTIVITY

We have completed examination of the anisotropy of the upper critical field  $H_{c2}$  in Nb<sub>0.53</sub>Ti<sub>0.47</sub>/Ge multilayers. For very thin NbTi layers, two-dimensional behavior was observed near  $T_c$ . Earlier extrapolations indicated  $H_{c2}$  approaching 40 tesla. Measurements extended to lower temperatures show that  $H_{c2}$  is limited to about 15 tesla because of paramagnetic limiting.

Spin-glass behavior was discovered in a pseudobinary uranium-based actinide system,  $U_xY_{1-x}B_4$ , over the range  $0.1 < x < 0.5$ .

Quasihydrostatic pressures up to 100 kbar were produced in a self-locking clamping device for resistance measurements at low temperatures and high magnetic fields in solid state materials. The first pseudobinary system showing "heavy fermion" behavior was observed in  $U(In_{1-x}Sn_x)_3$  for  $0.45 < x < 0.80$ .

Hot extrusion, powder metallurgy (P/M) processed Nb<sub>3</sub>Sn has been made with billets up to 2 in. o.d. P/M processing with these initial extrusion technologies indicates that the process should be transferable to industrial scale.

A cooperative program with Intermagnetics General Corp. (IGC) has been carried out on a Small Business Initiative Research (SBIR) grant funded by DOE to IGC for P/M processing of Nb-Al materials as high field superconductors.

Recently DOE funded Supercon, Inc. for an SBIR program for P/M processing of Nb<sub>3</sub>Sn. This is also a cooperative program with industry which will be in progress during the next year to evaluate industrial scale P/M fabrication.

The mechanical and electrical properties of a new Nb/Cu metal matrix microcomposite were evaluated. This industrial high strength conductor is suitable for applications to large systems requiring high strength and good electrical and thermomechanical properties.

Powder metallurgy processing of Nb<sub>3</sub>Sn with Ti additions to the Sn core has been used to obtain high field superconducting wires with critical current densities of  $10^4 A/cm^2$  up to 21 tesla.

A paper entitled "Versatile and Sensitive Vibrating Sample Magnetometer" by S. Foner has been chosen as a Citation Classic.

## RESEARCH IN THIN FILM SUPERCONDUCTIVITY

We have observed a magnetic proximity effect in a superconducting thin film in contact with an insulating film of rare-earth oxide. Spin-polarized tunneling measurements in an applied magnetic field indicate that electrons in the superconductor experience a magnetic field more than 2 tesla greater than the applied field. This effect may be useful for studying surface magnetism in non-metallic magnetic materials.

## LOW TEMPERATURE AND MAGNETIC FIELDS

The mission of the Low Temperature and High Magnetic Field Facility at the National Magnet Laboratory is to provide the unusual combination of very high magnetic fields and very low temperatures for the fundamental study of condensed matter systems. Highlights of developments at the Facility in the last year may be divided into three sections: facility development, advances in instrumentation, and scientific progress.

**Facility Development:** A new special low temperature refrigerator which allows the rapid change of experiments (the so-called top-loading dilution refrigerator) is in the final stage of installation. This will join an existing refrigerator which will continue to service long-term experiments. Both refrigerators share the common advantage of high field Bitter magnets, a superconducting moderate field magnet, instrumentation pool and specially trained personnel. In anticipation of the new refrigerator, substantial modifications have been made to the laboratory to accommodate the top-loading capability. Full operation is expected to commence in late July, 1986.

**Advances in Instrumentation:** One of the most significant achievements concerns the success in running an experimental sample at very high pressure (7.5 kbar) at low temperatures (less than 0.1 K) and a field of 20 T. The ability to achieve high pressures under these conditions (which have profound effects on the physical properties of many materials) has provided a new dimension to the capabilities of the facility. Progress has also been made in the area of primary thermometry in high magnetic fields, where nuclear orientation and helium-three melting curve thermometers are under investigation. Further advances in high sensitivity magnetometers which can operate in high field magnets have also been made. Significant advances have also been made in the area of calorimetric measurements below 0.5 K to 20 tesla. Specific heat measurements, which are crucial to the understanding of the bulk properties of material, become unusually difficult in this range of temperature and magnetic field, and considerable effort has been made to address this problem. Finally, high stability tunnel diode oscillator circuits (which are used in many signal detection schemes) have been demonstrated to operate reliably in high magnetic fields.

**Scientific Progress:** Progress has been made in the understanding of the physical properties of novel condensed matter materials. Most prominent are the magnetic field induced phase transitions in organic conductors, the unusual superconducting and magnetic behavior of heavy electron systems, and the metal-insulator transition in bulk and thin film materials. Worthy of special mention, is a difficult experiment to explore the high magnetic field dependence of the physical properties of the quantum gas, spin-aligned atomic hydrogen. These various experiments involve dozens of researchers from many institutions.

## SEMICONDUCTOR RESEARCH

We have investigated the exchange interaction between semiconductor carriers and the magnetic ions in semimagnetic semiconductors such as (Cd,Mn)Te, (Cd,Mn)Se and (Zn,Mn)Te. High magnetic fields to 70 tesla are used with photoluminescence, Raman scattering, Faraday rotation and nonlinear optics. Multiple quantum well structures made from (Cd,Mn)Te, (Zn,Mn)Se and (Ga,Al)As were also studied with optical and transport methods.

## LIQUID CRYSTALS

The distribution of micelle shapes in a system of anisometric micelles was obtained for the very first time. The effects of added electrolyte and cosurfactant on a micellar liquid crystal were investigated, with rather significant changes in the pretransitional behavior noted. The first investigation of pretransitional behavior in a re-entrant nematic-isotropic phase transition was made. Virial corrections to the orientational susceptibility of elongated rods (tobacco mosaic virus) were measured, and it was noted that the transition to an ordered phase is a partially thermally-driven (rather than athermal) process, contrary to previous thought. Macroscopic biological elongated tubules were oriented in high fields, resulting in new information about their structure.

#### MAGNETIC RESONANCE IMAGING FACILITY

M.I.T. has been engaged in a major initiative in the development and use of two new technologies for medical research and diagnosis. They are magnetic resonance imaging (MRI) and magnetic resonance spectroscopy (MRS). Using these technologies it is possible to peer deep within the human body as gently and clearly as we view its surface but with even greater specificity and sensitivity to anatomic and physiologic changes.

To carry out the Institute's comprehensive program of research in this pathbreaking area, M.I.T. created a new Magnetic Resonance Imaging Facility to serve as a center for basic research on human biology and disease. The MRI Facility is a joint venture by two M.I.T. interdisciplinary divisions - Whitaker College of Health Sciences and Technology and the Francis Bitter National Magnet Laboratory - who have pooled their resources, personnel, and expertise for this endeavor.

During the past year an agreement was signed whereby Siemens Medical Systems, Inc. will donate a complete second generation whole body 1.5 tesla imaging/spectroscopic system which will become part of the instrumentation complement of the MRI Facility. Installation of this apparatus is scheduled to start in December, 1986. Under an IBM-sponsored program to develop advanced MRI instrumentation, staff of the Facility have placed into operation a 1.5 tesla brain scanning apparatus. This system embodies such key features as a highly homogeneous superconducting magnet, a unique set of pulse gradient coils and versatile spectrometer electronics for data acquisition. This instrument is now being used to produce high quality images of human brain and to carry out in-vivo spectroscopy of humans. In addition, a high field imaging/spectroscopic instrument utilizing a 4.7 tesla, 40 cm bore magnet and the M.I.T./IBM spectrometer control electronics and software will be installed in November, 1986. This equipment will be dedicated to studies on animals and is being acquired under support from the National Institutes of Health and the Naval Blood Research Laboratory.

A number of research linkages have been established between the MRI Facility and investigators from teaching hospitals in the area. These include Massachusetts General Hospital, Massachusetts Eye and Ear Infirmary, Children's Hospital, West Roxbury V.A. Hospital and the Brigham and Women's Hospital. Professor Robert W. Mann, Whitaker Professor of Biomedical Engineering is interested in pursuing research at the MRI Facility in the area of computer-assisted surgery. During the next year it is anticipated that the MRI Facility will be fully equipped and operational with a broad research program underway.

#### SOLID STATE NUCLEAR MAGNETIC RESONANCE

Composite pulses are an important method for achieving broadband or frequency-tailored excitation in NMR. This year, it has been discovered that composite pulses possessing a characteristic called conjugate symmetry possess very convenient phase characteristics which should make them particularly useful. A new class of sequences based on this characteristic is being developed, which will be tested for broadband NMR excitation and for NMR solvent suppression.

#### MAGNET TECHNOLOGY

i) Pulsed Fields.

A 50 T pulsed field was achieved in close agreement with the prediction of design codes. Design of a 75 T pulsed field magnet is underway.

ii) 14 T NMR.

Development of niobium-tin coils for this system continued. A 13.5 T field was achieved.

iii) 34 T Hybrid.

Design of a new 34 T hybrid magnet system for the facility has proceeded to the ordering of the niobium-tin conductor and construction of a winding system for trial winding.

iv) Water-cooled Magnets.

A radially-cooled monohelix insert coil of new principle has been successfully tested in the hybrid magnet. Together with holmium pole pieces, it has generated the world's record dc field of 33.6 T.

#### APPLIED MAGNETISM

With DOE support, new work on magnetic conversion of pyrite by selective microwave heating has led to improved high gradient magnetic desulfurization of coal, important for acid rain control and the utilization of U.S. energy resources. A new highly selective continuous magnetic particle separation technique developed with NSF funding has produced separators with applications in biological cell sorting which is important for immune reaction studies, diagnostics and therapy.

LOW FIELD LAB

Experimental studies of magnetoencephalograms (MEG's) produced by natural and artificially implanted electrical sources in the rabbit brain have been completed; these studies have confirmed several fundamental theoretical aspects of MEG's. Theoretical and computer modeling studies of the effects of various experimental measurement errors on the accuracy of localizing electrical sources in the brain using MEG's have been completed and published.

PETER A. WOLFF

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## Center for Cognitive Science

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During the academic year 1985-1986, the Center for Cognitive Science initiated or continued a variety of programs designed to foster interdisciplinary research in human cognition. These included the development of the Human Subjects Laboratory, a program for visiting scientists and postdoctoral fellows, an affiliates program, a members program, a series of seminars and colloquia, an Occasional Paper publications program, the Lexicon Project Working Papers, and a program of financial support for research initiatives within the Center. Each of these activities is coordinated through the Center's Working Group, which, by means of a committee structure, reviews all proposals and approves expenditures for those programs judged worthy of support.

### The Multi-User Laboratory

Since 1981, the Multi-User Laboratory of the Center for Cognitive Science has provided the cognitive science community at MIT with computational facilities for data analysis and on-line control of experiments in perception, cognition, and language. The Laboratory is the principal experimental research facility for graduate students and faculty in linguistics and in human experimental psychology, and serves the visiting scientists and postdoctoral fellows in residence at the Center and the Psychology Department each year. In addition, undergraduates taking Subject 9.63, "Laboratory in Cognitive Science", use it to carry out their weekly lab assignments.

The Central facility in 20C-231 contains a PDP 11/44 running Berkeley UNIX, two LSI 11/03 minicomputers dedicated to real-time control of experiments, subject testing stations equipped with video monitors, headphones, slide projectors and associated peripherals such as printers, plotters, and tape drives. In addition, the Multi-User Lab maintains two satellite labs in the Psychology Department (E10), each with an LSI 11/03 subject testing station, and hardwired connections to the central computer in Building 20. The main computer can emulate each of the smaller laboratory machines, allowing users to edit and compile their experimental control programs without actually occupying the lab. Programs use locally-developed commands that insulate the user from idiosyncrasies of the hardware interface to lab peripherals; for example, there are commands that show text at a given screen position for a specific duration, or that advance a slide projector and open a shutter.

Last year the Center Lab expanded in three areas. Most important, the Lexicon Project, under a grant from the System Development Foundation, will be bringing its work on the construction of computerized dictionaries for several languages into the Center. To support this effort, a Microvax II computer was purchased, which will also be used for statistical analyses and simulation of cognitive processes. The second area of expansion is in facilities for experiments on visual processing, and includes the purchase of equipment to record eye movements, and of a 3-D solid modeling graphics system. Finally, a program to edit and analyze speech waveforms has been completed and is in the process of being implemented as a usable system.

### Research

The Center continued to support two major research projects. The first project, "Arguments and Argument Positions", is under the general direction of Professor James Higginbotham of the Department of Linguistics and Philosophy. This project proceeded through the discussion and planning stage to the production of several essay-length manuscripts by the principal investigators and aims at a work of approximately 250 to 300 pages.

The volume, tentatively entitled Arguments and Argument Positions, will be jointly written by James Higginbotham of MIT, Howard Lasnik of the University of Connecticut, and Edwin Williams of the University of Massachusetts, Amherst. This work will have four chapters. The first will include a brief historical review of the conception of an argument of a verb or other linguistic items, the connections between classical notions, such as transitive-intransitive and subcategorization, with their counterparts in contemporary work, and the theoretical problems posed by the nature of "understood" arguments in syntactic and semantic theory. The second presents in some detail a modified form of the type of theory of arguments and binding first developed in Chomsky's "On Binding," and Lectures on Government and Binding. The third chapter considers a number of the major issues that confront the Government and Binding theory in any of its standard forms, including implicit arguments and the proper analysis of quantifier-binding. The fourth and final chapter will attempt to spell out the semantics underlying the theses of the previous three chapters.

A second major research project at the Center is the Lexicon Project. This project, under the supervision of Professors Kenneth Hale and Samuel Jay Keyser, is supported by a grant of \$750,000

from the System Development Foundation. This project is concerned with the question of the proper format for a lexical entry. It is presently engaged in developing lexicons for a wide variety of languages, including Berber, English, Hopi, Warlpiri and Winnebago. Various dictionary programs are also being developed and implemented to facilitate the use of these lexicons as research tools.

#### The Visitor Selection Committee

During the academic year 1985-86, the Center hosted ten postdoctoral fellows: two in psycholinguistics, five in linguistics, one in neuropsychology, one in spacial-visual cognition, and one in psycholinguistics and aphasia research. It also sponsored one visiting scientist in philosophy.

#### The Affiliate Program

The Center continued its affiliate program which provides formal status for individuals who are connected with Center research, but are not in residence at MIT. Affiliates are individuals who are working actively in the field and observers of the field who wish to have an affiliation with the Center. Currently there are 18 affiliates.

#### The Member Program

In addition to the affiliate program, the Center maintained its Member Program which provides individuals within the MIT community formal affiliation with the Center. The program was designed for individuals whose interests significantly overlap with, and support the intellectual goals of the Center. At present there are thirteen designated Members of the Center: Professors Ned Block, Jerry Fodor, Kenneth Hale, James Higginbotham and Richard Larson of the Department of Linguistics and Philosophy, Professors Emilio Bizzi, John Hollerbach, Whitman Richards, Edward Smith and Jeremy Wolfe of the Department of Psychology, Professor Robert Berwick of the Department of Electrical Engineering and Computer Science, Professor Suzanne Flynn of the Foreign Languages and Literature Department, and Dr. Stefanie Shattuck-Hufnagel of the Research Laboratory of Electronics.

#### Seminars and Colloquia

During the 1985-86 academic year the Center continued to support three kinds of seminars. The Center for Cognitive Science Seminar Series, a monthly seminar, is open to the Cambridge community at large and presents papers on a variety of topics relevant to the Center. The papers are distributed to seminar participants before the meeting. At the seminar itself, a commentator or commentators present the paper, the author follows with comments, and the paper is then thrown open for general discussion from the floor. Last year over 500 members of the community attended the seminars. Vision Lunches are weekly lunch-time talks sponsored jointly by the Center for Cognitive Science and the Department of Psychology and held in the conference room of the Psychology Department. Twenty-five lunch talks were given last year.

Finally, the Lexicon Project Seminar was a year long weekly seminar devoted to talks on the theory of lexical entries, drawing on a wide variety of languages, including Warlpiri, Winnebago, Berber, and English. Twenty-five Lexicon Seminars were given last year.

#### The Occasional Paper Program

The Center for Cognitive Science sponsors a series of Occasional Papers. The papers attempt to inform fellow workers in the field of the current research being done at the Center. To date thirty-two Occasional Papers have been published.

#### The Lexicon Project Working Papers

Lexicon Project Working Papers are sponsored by the Center. These papers describe the work carried out at the Center in conjunction with the Lexicon Project. The aim of these papers is to report current research on the Lexicon Project. To date, five papers have been published.

#### Publications

The Center for Cognitive Science has supported a variety of publications by making its resources available to visiting scientists, postdoctoral fellows, predoctoral fellows, and to affiliated faculty. As of the end of the academic year 1985-86, a total of seven books and 80 articles have been published as a result of Center support.

SAMUEL JAY KEYSER

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## Center for Materials Science and Engineering

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The Center for Materials Science and Engineering (CMSE) was founded in 1960 for the study of the structure and properties of materials. Currently, major funding for the Center is provided through the Materials Research Laboratory program of the National Science Foundation (NSF). The Center operates major research facilities which provide state-of-the-art instrumentation and the expertise of professional staff to foster research projects of the materials community at MIT. We also provide seed funding for a small number of exciting projects for faculty seeking to develop new ideas, and we fund collaborative research on major problems in materials science. Last year we reported funding research in six major thrust areas. To use our resources more effectively, these activities were somewhat reorganized, the least successful activities were discontinued, and a new thrust area on innovations in steel technology was added; consequently the CMSE provided funding for five areas of thrust during the past year.

Seed funding for eight research projects was provided during fiscal 1986. We hope to be able to fund three or four new projects during the coming year, but will have to deal with Gramm-Rudman-Hollings mandated budget cuts that amount to half of the amount we normally allocate for seed funding.

With the arrival of major items of equipment and the completion of space renovations, our new facility for the production of materials by rapid solidification techniques came closer to full scale operation. The Center also took delivery of a Cambridge 250 Mark III scanning electron microscope last year and it has been installed in renovated space carefully chosen to provide an environment of low vibration and magnetic fields. The initial steps have been taken to establish an x-ray diffraction facility in collaboration with the department of Materials Science and Engineering. The facility will contain two rotating anode sources and be used for both laboratory instruction and research. The major items of equipment have arrived and will be installed as soon as space renovations are completed. A long-awaited milestone was reached when the MIT/IBM spectrometers on the x-ray ring at the National Synchrotron Light Source (NSLS) became operational as a central facility late this fall.

Our weekly colloquium on a wide range of topics in materials research was held during the academic year, and we provided support to a seminar series in condensed matter physics and to another in polymer research. The central facilities offered training courses during Independent Activities Period as well as at appropriate times during the school year.

There have been some administrative changes in the Center. Our Administrative Officer, Lydia White, retired after 17 years of service to the Center for Materials Science and Engineering; the Fiscal Administrator, Deirdre Dow-Chase, has been promoted to Administrative Officer.

Below, we briefly outline the research activities of our five thrust areas during the past year. The names and departmental affiliation of the individual researchers are given at the end of each section.

### Deformation and Fracture at High Temperatures

In this thrust area there have been important changes in emphasis away from mechanical testing of industrial alloys toward more generic studies and modeling of mechanisms of both deformation and fracture. The goal is to advance basic materials science by obtaining a sound understanding of the mechanistic basis for the deformation and fracture behavior of metallic alloys at high temperature, as well as to develop mechanism-based laws for the rate of deformation and damage development under various conditions. This basic understanding can be used to extrapolate empirical testing results to different operating conditions and also provide a way to predict remaining life and current state of damage in parts with an uncertain history.

During the past year there has been progress on several levels. First, experiments indicate that deformation processing is a viable means to develop additional strength by causing anisotropic grain growth. It is more difficult for cracks to propagate across grains than between them, thus a coarse anisotropic grain structure can give improved high temperature creep resistance. Fracture occurs across grains, so in the best alloys we have produced so far, the strength of the material is determined by that of the grains. On the second level, simulation experiments have been developed that use thin disks and induction heating to produce sample degradation closely similar to that observed in service. This provides a controlled way to explore and understand the effects of high temperature service on alloys.



The initial results show that NiAl protective coatings degrade by spallation of Al<sub>2</sub>O<sub>3</sub>. A computerized dc potential drop system has been developed and put into use for intermediate level property measurements; it has proved possible to use this apparatus to distinguish whether failure at stress rising notches is by cavitation or by crack initiation. At the level of fundamental generic studies, lattice dislocations on (111) planes have been found to act as coarsening sites for gamma prime precipitates in the superalloy Inconel X-750; the mechanism works by relieving some of the three percent positive misfit strain.

Faculty/Department: Professors S. Allen, N. Grant, R. Pelloux (Materials Science and Engineering), A. Argon, L. Anand, F. McClintock, and D. Parks (Mechanical Engineering).

#### Defects in Semiconductors

This thrust area has settled down with two major themes. The first is to identify the defect structures most important in a given material, and the second is to understand electronic transport properties in materials with high-defect densities. Progress has been made in both these efforts.

Studies of time-resolved photoluminescence in amorphous and crystalline As<sub>2</sub>Se<sub>3</sub> indicate that the luminescence center is a triplet in both phases; it is therefore hard to understand why the optically-detected magnetic resonance signals are so weak. Concomitantly, an *ab-initio* calculation of the geometric structure and electronic parameters of monoclinic As<sub>2</sub>Se<sub>3</sub> has begun. Calculated parameters are within a few percent of the measured ones and, because of the complexity of the crystal, we expect defects in the crystal and the amorphous phase to be similar. An investigation of the structural and electrical properties of polycrystalline silicon thin films and their dependence on deposition parameters has also been started. In the coming year, this will concentrate on *in situ* doping of silicon in a plasma-enhanced CVD process. The goal is to develop high quality polycrystalline thin film transistors that could be used for flat panel displays.

On another theoretical front, a model has been developed for hydrogenated amorphous silicon which explains the puzzling low band mobility of the electrons. The model also explains the unexpected observation of photo-induced spins even in very low quality material. In addition, computer simulation of the electron glass problem has been nearly completed; many "data" on the time-dependent dielectric response for two-dimensional materials have been accumulated. As a first step toward observing the predicted glass-like behavior, transient optical and transport methods have been started. Theoretical work on the problem of an x-y model in a random anisotropy field has just begun. Preliminary results give the unexpected result that there are many "ground states" in the theoretical solution that have a significant magnetic moment.

There has been excellent progress in using molecular beam epitaxy (MBE) to grow high quality epitaxial heterostructures in the GaAlAs/GaAs and GaInAlAs/InP lattice-matched systems, as well as to produce heavily doped compensated MBE layers for the study of localization and Coulomb interaction effects. Work will continue on high electron mobility transistor layers and the use of ion implantation to produce n<sup>+</sup> sources, drain contact regions in self-aligned structures, and to control device thresholds.

Faculty/Departments: Professors D. Adler, M. Dresselhaus, C. Fonstad, R. Reif (Electrical Engineering and Computer Science), J. Joannopoulos, M. Kastner, and P. Lee (Physics).

#### Phases and Phase Transitions

This group was pleased by the award of the 1985 Nishina Memorial Prize to Professor Tanaka for his pioneering work on phase transitions and critical phenomena in polymer gels. This is the highest award of the Physical Society of Japan, and recognizes "exceptional scientific achievement in the field of nuclear physics and related areas." Professor Tanaka's research was initiated under CMSE support, and his association with this thrust area has continued to be significant.

During the past year quasielastic light scattering has been used to observe the Brownian motion of hemoglobin in living red blood cells, while simultaneously measuring its optical absorption spectrum. These non-invasive tools will provide essential new information on the aggregation which is responsible for sickle-cell anemia. Preliminary results indicate that the process of aggregation differs markedly from cell to cell and that there is some aggregation even in normal cells.

Some exciting x-ray scattering studies of ordering in liquid crystals were carried out at the NSL facility. These elucidate the melting process in crystals. A material has two distinct types of order associated with its existing in a crystal phase. The first type is positional order locating each molecule or atom on the appropriate lattice site. The second type, commonly called bond orientational or BO order, specifies the well defined directions of imaginary lines joining neighboring molecules, which are also the directions of the crystalline axes. Until recently, most solid state physicists did not appreciate that these two kinds of order need not vanish together. It is possible to have a phase of matter in three dimensions without long range position order but with long range BO order. (The inverse is not possible.) That is, in principle, there can be a phase in which one knows what directions to go in to encounter other molecules, but not exactly how far. The experiments showed that the smectic I phase of

liquid crystals is an example of this unusual state of matter, and were done on a single domain sample. They showed the quantitative growth of the BO order parameter, as well as its higher harmonics, as the temperature was lowered. The nth harmonic was found to scale as the fundamental to the power  $n+0.3n(n-1)$ . This scaling can be explained quantitatively by a model in which the harmonics are regarded as secondary order parameters, and the powers are crossover exponents from an XY model to broken symmetry states of uniaxial, three-state Potts, cubic, hexagonal, etc. interactions as the harmonic number n is increased. It is interesting that a synthesis of many problems in critical phenomena is required to understand this partial melting, and that further experiments should enable the measurement of quantities that have, until now, been impossible to measure.

Faculty/Department: Professors C. Garland (Chemistry), G. Benedek, A.N. Berker, R. Birgeneau, T. Greta, J.D. Litster, T. Tanaka (Physics), S-H. Chen (Nuclear Engineering), and A. Aharony (visitor to CMSE).

#### Polymers

The novel synthesis of polymers using transition metal based catalysts has been the goal of several members of this thrust area. So far, two monomers have been synthesized, polymerized, and characterized. Future work will begin with the catalyzed synthesis of diacetylene oligomers, which are unusual and perhaps unique forms of this polymer. Calculations of the electronic structure of these materials have also been started.

Another goal has been the synthesis rigid rod polymers with a predetermined degree of structural rigidity. In the first materials made, the regularity was small due to the relatively small difference in reactivity of the monomer amino groups, but the effect of regularity on solubility was large, and good thermal stability was retained. These results are all in good accord with predictions. Future research will use purified monomers with much larger differences in reactivity.

New microelectrode techniques have been used to measure rate constants for redox processes occurring at polymer solution interfaces, it has been possible to develop theoretical methods to calculate these rate constants in strongly acid solution, and also predict large changes in optical absorption on oxidation.

Work has continued on investigating the mechanical toughness of semi-crystalline polymers (e.g. Nylon-6) using high-resolution scanning electron microscopy, and x-ray scattering on plastically deformed materials. In the future, stress and temperature jump experiments will be done to determine the mechanisms and rate of plastic flow of the Nylon-6. Another study will employ solution blended Nylon and polybutadiene to form rubber modified Nylon, which will be studied by the same methods.

Faculty/Department: Professor R. Schrock, R. Silbey, M. Wrighton (Chemistry) U. Suter, R. Cohen (Chemical Engineering), and A. Argon (Mechanical Engineering).

#### Innovations in Steel Technology

This is a newly formed group which seeks to provide the scientific basis of a new steel technology aimed at specific property objectives that are important to industry. The goal of one sub-group is to address precipitation hardening, plastic shear instability resistance, and intergranular hydrogen embrittlement resistance in ultrahigh strength martensitic alloy steels. A second sub-group aims to control the amount and stability of dispersed austenite to provide enhanced uniform ductility under plane strain conditions and improve the formability of sheet steels of interest to the automobile industry. Two universities (Harvard and MIT), four private industrial companies (Bethlehem Steel, Carpenter Steel, General Motors, and LTV Steel), and two government laboratories (Army Mechanics and Materials Research Center, and Los Alamos National Laboratory) participate in the program.

In the first sub-group three different binary alloys have been prepared for study of the effect of dislocation recovery resistance on heterogeneous precipitation in martensitic steels. Preliminary measurements indicate a unique effect of Co, which is being investigated further by neutron scattering. A thermochemical database system has been set up on a VAX at MIT and will be used for calculations predicting other alloys suitable for precipitation studies. Preliminary field ion microscopy studies have also begun in collaboration with Oxford University, while we await the delivery of our own field ion microprobe.

The second sub-group is focussing on austenite particle size refinement as the most efficient method of increasing austenite stability. Initial research has centered on the carbide nucleation of austenite to obtain fine dispersions. Bethlehem Steel has provided samples of a multicomponent low alloy steel suitable for study; in collaboration with MIT researchers, the carbide precipitation behavior has been mapped out and carbides of 100 nm and 10 nm size have been identified. The nucleation of austenite by these will be investigated

The steel research group was saddened late this fall by the passing of Professor Thomas B. King, who had been exploring the modification of void-nucleating dispersed particles via melt control and solidification processing.

Faculty/Department: Professors S. Allen, M. Cohen, M. Flemings, T. King, G. Olson, and J. Vander Sande (Materials Science and Engineering).

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## Division of Comparative Medicine

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During the past year several changes in the administrative functions of the Division of Comparative Medicine (DCM) have followed the complete implementation of new Public Health Service policy regarding the use of vertebrate animals in biomedical research. Several DCM individuals now work in support of the animal research protocol review conducted by the Institute Committee on Animal Care, and DCM animal ordering and monitoring procedures were modified reflecting the increased institutional accountability in this process. Equally evident to institutional animal users during this past year was the increased emphasis DCM has given to animal facility security in response to the possibility of incursions by individuals or groups intolerant of animal research. Members of the Division also have been active in garnering the support of investigators in developing public education programs about the use of animals in research to protect this vital activity.

During the past year there was a significant expansion of the clinical services, diagnostic capabilities, and research activities of DCM with an attendant increase in the personnel dedicated to each of these areas. In the clinical area DCM recruited a veterinarian to supervise the animal surgical facility used by investigative personnel and to provide excellent and consistent management of surgical patients. In the diagnostic area, DCM added a comparative pathologist and a virologist, both of whom are contributing also to the research activities of the Division. Five additional new people are full time participants in the DCM diagnostic or research programs.

Although there have been no substantive operational changes in the animal facilities, the consolidation of animal research activities has resulted in less of a need to utilize the older satellite animal facility in E20. This has resulted in a more efficient use of animal care personnel. Two key changes in the management personnel of the animal facility were the replacement of the Manager and the Facilities Coordinator. The Division is currently evaluating the work load distribution and the cost centers within the animal facilities to allow better definition of the per diem structure in conjunction with recently acquired computer software. The Division became the 25th animal facility in the country to install General Computer Systems' software for animal facilities management. The system produces complete cost-accounting for the animal care operation and monitors the distribution of labor, materials, and services for each species of animal housed. The animal purchase portion of the program matches each purchase with the appropriate protocol and generates cage cards when the animals arrive in the facility. The program has increased the Division's efficiency at processing the information required in the present regulatory environment.

The Division has continued to devote considerable effort to the education of veterinarians and veterinary students interested in careers in laboratory animal medicine. DCM hosted veterinary students from Tufts University Veterinary School throughout the year as well as veterinary students from other universities through a summer externship program. DCM also initiated a summer session short course during 1985 entitled "Infectious Diseases of Laboratory Rodents: Recent Advances," which had forty-seven registrants representing institutions from across the country. The success of this program was encouraging, and DCM is committed to repeating this format in the future. The DCM postdoctoral training program in comparative medicine continues to thrive: two individuals completed training and excellent replacements have been recruited. The new Postdoctoral Associates primarily will be integrated into the clinical and diagnostic activities of the Division but are also available for the support of Institute animal research activities. Three Visiting Scientists and a Postdoctoral Scholar are engaged in research programs affiliated with DCM.

Animal related research at the Institute has been stable during the past year with the Division continuing to maintain an average daily research animal population of approximately 13,000 animals. Research activities within the Division itself continue to flourish. The Division's NIH funded regional animal research and diagnostic laboratory entered its 11th year of funding and continued to provide high quality diagnostic support services for animals utilized in biomedical research; this grant also enables DCM members to pursue research topics of fundamental importance in the area of comparative medicine.

Extramural support for the Division consists of seven NIH grants for which DCM staff members are either principal investigator or co-principal investigator, a Veterans Administration contract, and monies derived from Boston-based biomedical research institutions that utilize our diagnostic laboratory facilities.

During 1985-86, 24 articles by DCM faculty and staff were published or in press. The Division also has published 12 abstracts during the past year, and has presented numerous papers at both national and international symposia on comparative medicine.

CHRISTIAN E. NEWCOMER, VMD

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## Energy Laboratory

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The main purpose of the Energy Laboratory is to encourage problem-oriented research on a broad range of energy issues through the interactive participation of people drawn from most of MIT's academic departments. That research addresses one or more of the following four broad questions: 1. How can fossil fuels, particularly low-quality fuels, be burned more efficiently, economically, and safely? (The word "safely" emphasizes environmental and health considerations.) 2. How can fossil, nuclear, and renewable energy resources be converted to more useful forms more efficiently, economically, and safely? 3. How can energy-intensive materials and methods be improved or replaced? 4. What are the interactions among energy, the economy, and society?

Operating expenses of the Energy Laboratory during fiscal 1986 exceeded \$12 million compared to \$10.7 million in FY85 and \$9.3 million in FY84; thus, our growth has resumed despite lower national priorities for energy. Our sponsorship is now highly diversified with about half of fiscal 1986 funding coming from the private sector (about one hundred organizations) and about one quarter from the US Department of Energy; at one time DOE provided more than 60 percent of our support. About 80 faculty plus about 250 graduate and undergraduate students from 17 academic departments (plus other MIT units) participated in Energy Laboratory projects during the year; no one department accounted for more than 30 percent of our volume. That diversity helps to maintain the multidisciplinary character of research we seek, and that academic participation helps to weave our activities as closely as possible into the educational fabric at MIT.

In May, Mr. David O. Wood was appointed Director of the Center for Energy Policy Research (CEPR) replacing Mr. Loren C. Cox who resigned from MIT. Mr. Wood is participating in a Sloan School/Department of Economics study to consider how the CEPR approach to research organization and funding might be extended to non-energy areas of economics and finance. Also in May, Professor David C. White assumed cognizance for the Electric Utility Program, replacing Professor Kent F. Hansen who shifted his attention to development of new programs.

Work at the Laboratory's Northeast Residential Experiment Station ceased in May with completion of the program. That work was concerned with evaluating the design, performance, and economics of solar photovoltaic systems tied into electric power grids and intended for use in residences.

The First International Symposium on Innovative Mining Systems was held at MIT in November. Over 170 people from 15 countries attended. The symposium was arranged by the Laboratory's Center for Innovative Mining Systems working with The Pennsylvania State University, MIT's collaborator in the Center. Professor Carl Peterson, the Center's director, has taken a further step as the prime mover in organizing the Excavation Research Institute (ERI), an arm of the American Society of Mechanical Engineers. The ERI is a consortium of at least six key universities and numerous associated universities which will address a broad range of surface and underground mining and tunneling activities, with both public and private funding.

Specific research accomplishments during the year covered a large and diverse set of topics. Some of the topics of more general interest were summarized in our quarterly research bulletin, e-lab, under the following headings, grouped here in four categories:

### Electric Power Distribution

- Understanding electrical "burns"
- Monitoring electric power transformers
- Protecting underground transmission lines
- Spark prevention in electric power apparatus

### Internal Combustion Engines

- Faster burning in spark-ignition engines
- Improving the diesel combustion process
- Modeling diesel combustion
- Insulating diesels with ceramics

### Options Techniques for Valuing Investments

- The options approach: offshore oil leases
- Options with flexible development schedules
- Options with operating flexibility: natural resources
- Options within complex tax systems

#### Other Research

- Health effects of coal combustion
- Making solar cells using lasers
- Improving silicon nitride
- Monitoring the use of residential appliances
- Seasonal use of gas to reduce acid rain

Information on all the projects active in the Laboratory during fiscal 1986 may be obtained from the report entitled Project Summaries, July 1, 1985 - June 30, 1986. The following material describes the major thrusts of the Energy Laboratory's principal research groups at the end of the year:

#### RESEARCH GROUPS

The Combustion Research Facilities program emphasizes parallel modeling and experimental investigation of combustion processes of gaseous, liquid, and solid fuels in both steady and unsteady operation. A special feature of the experimental studies is that fundamental flame data are obtained in large-scale pilot plant combustors in which the combustion-heat transfer processes closely simulate industrial practice. (Professor Janos M. Beer, Scientific Director)

Research in the High-Temperature Reactions and Health Effects program concentrates on the oxidation and pyrolysis of fuels and on techniques for controlling emissions from these processes. Studies of the formation of mutagens in hydrocarbon combustion involve a team effort among engineering, analytical chemistry, and biological sciences. (Professor John P. Longwell, Program Director; Dr. William A. Peters, Program Manager)

The Synthetic Fuels Center is concerned with research on conversion of primary energy resources to liquid and gaseous fuels. Energy companies cooperate to support and offer guidance to the program. Current projects are investigating comminution, slurry rheology, generation of hydrogen, coal pyrolysis, hot desulfurization, refractory corrosion, reactions of microparticles, and dissociative adsorption of small molecules. (Dr. Malcolm A. Weiss, Director)

The Transportation Propulsion program conducts research related to improving conventional spark-ignition and diesel engines and on developing new engine concepts. Activities are based in the Sloan Automotive Laboratory and include fundamental and applied research on engine performance and emissions characteristics, engine fuels requirements, novel engine concepts and materials, and policy and technology studies. (Professor John B. Heywood, Program Director; Dr. Victor W. Wong, Program Manager)

The Energy Engineering program is a collaborative effort with the Idaho National Engineering Laboratory that focuses upon research in the engineering sciences needed to enhance energy use in technical industries. Active research areas include: thermal plasma materials processing; automated welding; engineering analysis and design methods; and fracture mechanics/fracture control. The research aim is to bridge the gap between the science base and existing industrial practice by providing methods, models, and data that will allow for improvement in technical products and processes. (Professor Kent F. Hansen, Program Director)

The Advanced Energy Materials program examines new and emerging technologies in such areas as electrodes and electrolytes for high-density batteries and fuel cells; synthesis of ceramic powders using laser heat sources; rapid solidification of molten ceramics; solar heating/cooling; amorphous photovoltaics; and broad band antireflective coatings. (Dr. John S. Haggerty, Program Director)

The Energy Markets, Pricing, and Regulation program conducts research on the structure and regulation of energy industries and markets, and the interaction between energy markets and the macroeconomy. Current research focuses on the structure and regulation of the international petroleum and US electric utility industries; analyses of energy demand and the relationship between energy prices and economic growth in both developed and developing economies; studies of international oil, gas, and coal markets; and development and application of new methods for capital budgeting and energy project evaluation. (Mr. David O. Wood, Program Director)

The Center for Energy Policy Research focuses on policy research and analysis and on making results available and useful to policymakers. With support from its Associates, a wide range of US and international corporate and noncorporate interest groups, the Center holds conferences and seminars to bring together key government and private organizations to work on energy-related policy issues. The work of the Center is done by faculty and students from several MIT departments (particularly the Sloan School of Management and the Department of Economics), by professional staff members from the Energy Laboratory, and by specialists from the Center's Associates. (Mr. David O. Wood, Director)

The Electric Utility Program serves to inform participating companies about ongoing MIT research activities, to identify and discuss utility needs and priorities, and to develop research projects responsive to those needs. The member organizations currently participating in the program include 16

utilities; 10 other organizations involved in supplying fuel, equipment, or services to the industry; and one government agency. (Dr. J. Derek Teare, Director)

The Nuclear program has the following broad objectives: 1) to provide direct technical contributions to nuclear plant reliability and safety; 2) to investigate possible improvements in nuclear plant design for more efficient utilization of nuclear fuel resources; and 3) to develop and communicate information that will contribute to public understanding of nuclear power. (Professor Neil E. Todreas, Program Director)

Research in the Environmental program seeks to evaluate the environmental impacts of energy-related facilities and the effects of controlling their pollutant emissions to air, water, and land. It involves a diverse range of projects, including cooling and waste disposal systems for electric power plants, water management issues associated with coal development, impacts of acid rain, and local and long range effects of air emissions. (Professor James A. Fay, Program Director; Dr. E. Eric Adams, Program Manager)

The Center for Innovative Mining Systems was organized together with The Pennsylvania State University to conduct research on advanced mining systems, initially emphasizing underground coal mining. (Professor Carl R. Peterson, Director)

The Energy-Efficient Buildings and Systems program examines the behavior of existing buildings and components and seeks to develop new technologies with better energy efficiency. Current projects include studies of the transfer and accumulation of moisture in structures retrofitted with insulation, heat loss from building foundations, and the insulating value and aging characteristics of closed-cell foam insulation. (Dr. Leon R. Glicksman, Program Director)

#### PUBLICATIONS

During the past year, Energy Laboratory research resulted in 32 technical reports and working papers, and about 92 other publications (journal articles, workshop and conference presentations, etc.). Energy Laboratory Headquarters maintains a complete list of reports and working papers as well as copies of Project Summaries and e-lab.

MALCOLM A. WEISS

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## Harvard-MIT Division of Health Sciences and Technology

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### ADMINISTRATION

This has been the first year of operation of the HST Division under its new administrative structure. The new organization has worked very well; communication between the two cooperating universities is now excellent; and the broad objectives of the Division have been reaffirmed. The Co-directorship has functioned smoothly, and reflects the common goals, priorities, and philosophies of the incumbents. Although both individuals are involved in all major management issues, Dr. Kitz has primary responsibility for the Biomedical Sciences (M.D.) Program, and Dr. Mark has primary responsibility for the Bioengineering and Physical Sciences Program. The Executive Group, consisting of Prof. James Adelstein (Dean for Academic Programs at HMS), Prof. Kenneth Smith (Associate Provost at MIT), and the Co-directors has met on a regular monthly schedule and has established good inter-institutional communication and cooperation. The Joint Faculty Committee, comprised of 28 individuals from the faculties of Harvard University, Harvard Medical School, and MIT meets monthly, and plays a central role in both academic and policy matters. Important subcommittees of the Joint Faculty Committee include the M.D. Admissions Committee, the M.D. Curriculum Committee, and the Harvard-MIT Committee for Biomedical Engineering and Physical Sciences. The latter committee functions as the graduate committee for MIT doctoral students enrolled in the Division. The Governing Board met in February 1986, and after approving the new administrative structure of HST, decided to dissolve itself as a formal part of the governance of the Division. Instead it recommended that a Visiting Committee be formed to provide the MIT Corporation and the Harvard Board of Overseers with periodic assessments of the Division's academic and research functions. The Visiting Committee is currently being defined.

At the request of Dr. James Adelstein, Dean of Academic Affairs at HMS, HST has formed a Promotions and Appointments (P & A) Committee. From time to time engineers are appointed to various clinical and basic science departments in the Harvard Medical School and often distinguish themselves to the point where they are recommended for promotion at HMS. These recommendations are forwarded to the HMS Promotions and Appointments Committee chaired by Dean Adelstein. His committee will now forward the dossiers of these candidates to the HST P & A Committee, the latter charged with assessing the quality of the candidate's research and educational contributions as an engineer. The HST committee, made up of distinguished members of the MIT and HST faculty, will also respond to requests from MIT departments to assess the medical contributions made by physician scientists recommended for promotion at MIT. Thus, HST is in a favorable position to influence the quality of these appointments and promotions, a very special privilege.

As part of a major reorganization effort, HST's Office of Research Development was phased out with the retirement of its Director, Dr. Irving Bernstein. The purpose of that office was to catalyze interdisciplinary and inter-institutional research focused on the problems of human health. This unique role of HST is now subsumed by a more broadly structured Research Development Committee chaired by Dr. Kitz. Its members include senior representatives of the Harvard, MIT and MGH faculties. The charge to the committee is two-fold: first, to catalyze the development of those important research activities that are properly aligned with HST's unique mission and secondly, to assume an overview function for those multiple research grants administered by the Division. It is in this manner that HST will continue to utilize its "good offices" to partially discharge its obligation to improve the quality of patient care through a greater understanding of human health problems.

### ACADEMIC PROGRAMS

#### Biomedical Sciences

The Harvard Medical School has embarked on an exciting new program of medical education patterned after the Oxford University model. The student body will be divided into five societies each with somewhat of a different focus and having dedicated faculty and resources. The M.D. Program of HST is one of the original societies, the other being the Oliver Wendell Holmes Society. The Medical School has committed new resources to the societies and has included HST's request for a five million dollar endowment in its current fund raising campaign. MIT will match that effort. Each of the five societies will be housed in a new educational building currently being erected on the HMS campus. Our HST Program, as one of the original societies, has been assigned new and markedly expanded space in the new building which will house HST officers at HMS, the students in our Biomedical Sciences Program, and teaching and educational resources of multiple design and function. These new facilities will be available in the Fall of 1987.



In keeping with the spirit of the Harvard Medical School to experiment with new pedagogic techniques, selected members of the HST faculty and Oliver Wendell Holmes Society have met on several occasions, including a full day's retreat at the Endicott House. Students were invited to critique their respective programs, a most insightful exercise. Combined teams of faculty redesigned an important course utilizing different teaching philosophies and pedagogic techniques. Several of these will be adopted by course directors for the HST programs.

In recognition of the success of HST's Biomedical Sciences Program, the Medical School has agreed to increase admission to HST from 25 up to 30 per year. The HST student body is selected because of its interest in research and the physical sciences of engineering, physics and mathematics. The students and their special HST programs have resulted in a record of distinction. Approximately a third are awarded MD/Ph.D.s. HST students continue to win a disproportionate fraction of honors at graduation. This year's 16 recipients of the M.D. degree included two magna cum laude and seven cum laude graduates. Included in this year's entering class are four Rhodes Scholars. The Biomedical Sciences Program of HST justly deserves its ranking among the best in the country.

#### BIOMEDICAL ENGINEERING AND PHYSICAL SCIENCES

Our broad objective is for the HST Division to become a unifying force for biomedical engineering education at MIT and Harvard, and to perform such functions as: coordinating interdisciplinary educational programs in biomedical engineering/physics, particularly those which are interdepartmental and which make use of clinical facilities; supporting departmental programs in biomedical engineering/physics; providing centralized information dissemination and recruiting for prospective students; coordinating development of new interdepartmental course offerings in order to avoid duplication and to serve the entire community; strengthening academic links to teaching hospitals; identifying needs for new faculty in biomedical engineering/physics; and assisting in raising resources to support existing and new programs.

A strong faculty committee was constituted this year to oversee the Division's activities in Biomedical Engineering/Physical Sciences. The Committee is comprised of 20 members representing the MIT Departments of Electrical, Mechanical, and Nuclear Engineering, Aeronautics/Astronautics, and Physics; Harvard University's Division of Applied Sciences; and HMS. The Committee functions as the Division's Graduate Committee to supervise the academic programs of its graduate students. In addition to students in the MEMP Program, the Committee this year has also assumed responsibility for those students in the MIT Interdepartmental Biomedical Engineering Doctoral Program. The Committee also reviews proposals for new courses and academic programs, supervises publication of the "Guide to Biomedical Engineering at MIT and Harvard" and other recruiting literature, defines new faculty needs, and sets funding priorities.

The Medical Engineering/Medical Physics Program has been restructured to permit increased efficiency and greater flexibility for the students while preserving the major objectives of the original program. In addition, Divisional Fellowship Funding has been reduced to a total of three semesters per student.

The HST Division, collaborating with the Department of Applied Biological Sciences, has proposed a new doctoral program in "Applied Biology in Medicine". Three students per year will be admitted to this program, pending the identification of suitable funding sources. The students will be admitted jointly to the Department of Applied Biological Sciences and to HST, they will pursue a graduate program in Applied Biological Sciences including the necessity of passing the doctoral qualifying examination in that department. They will take a number of courses in human biology and pathophysiology together with HST medical students, and will engage in a clinical training program entirely parallel to that taken by MEMP students. This program will be particularly attractive to individuals who desire to apply the technologies of biochemical engineering, biotechnology, or toxicology to problems in clinical medicine.

Six students completed the requirements for the Ph.D. degree in Medical Engineering/Medical Physics during the past academic year. All appear to be headed toward academic careers. Three have assumed junior faculty positions at major universities. Two have begun post-doctoral research positions, and one has transferred to Harvard Medical School as an M.D. candidate.

The academic year 1985-86 saw the culmination of a multi-year effort by HST to further its teaching and research programs by forming close relationships with the Massachusetts General Hospital. Several years ago, the MGH assembled its multiple patient-oriented engineering activities into a new Department of Biomedical Engineering with major service to patient commitments, but academic pretensions which would enable it to stand as a peer with the other clinical, research and teaching departments of Surgery, Medicine, Anesthesiology, etc. Primarily through the generosity of Mr. John Taplin and his family, Dr. Ernest Cravalho was appointed the first Edward Hood Taplin Professor of Biomedical Engineering in HST. He will be deployed on the MGH campus and head its Biomedical Engineering Department. Prof. Cravalho's charge is to improve the quality of care to patients by implementing

technologically-oriented programs of education and research for students and scientists at MIT, HMS, and MGH.

#### FACULTY NOTES

Prof. Richard Cohen was awarded tenure in the HST Division, and has accepted the responsibility of directing the HST Center for Biomedical Engineering. Dr. Irving London has remained active in HST affairs following his retirement as Director. He maintains an active research program, and has instituted for the first time an HST Alumni Association. In addition, he continues to teach and to advise students in the Biomedical Sciences Program.

The Co-directors wish to express their gratitude to the Presidents, faculties, and students of Harvard and MIT for their consistent support during this transition year. We are excited about the HST Division, and its role in focusing the combined resources of these two great institutions on developing new approaches to problems in human health.

RICHARD J. KITZ  
ROGER G. MARK

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## Mining and Mineral Resources Research Institute

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It is the policy of the Mining and Mineral Resources Research Institute (MMRRI) of MIT to utilize the available resources to support and encourage new initiatives in teaching and research that are related to minerals resources. Three graduate and five undergraduate students from the Departments of Civil Engineering, Mechanical Engineering, and Materials Science and Engineering have received support from the MMRRI this year. Important items of equipment have been purchased for the REMERGENCE Laboratory and for the Chemical/Process Metallurgy Group in the Department of Materials Science and Engineering.

Through the MMRRI, MIT continues its participation in the Generic Minerals Technology Centers for Pyrometallurgy and Respirable Dusts that are sponsored by the Bureau of Mines. Through the efforts of Professor Carl Peterson of the Department of Mechanical Engineering, the Institute for Innovative Excavation Equipment and Systems has been organized. The parent institution of this Institute is the American Society of Mechanical Engineers, and the member universities include MIT; the University of California, Berkeley; the University of Missouri, Rolla; Pennsylvania State University; Texas A and M University; and the University of West Virginia. This Institution will serve as the administrative structure through which the member universities may cooperate and participate in education and research efforts in close affiliation with industry, government, and other universities in programs of mining, tunneling, and excavation. This organization is an extension of the joint program of innovative mining and mine systems design between the Pennsylvania State University and MIT.

Professor John F. Elliott, Director of the MMRRI of MIT, has been named a member of the Minerals Resources Committee of the National Association of State Universities and Land Grant Colleges. He again received the Distinguished Professor Award from the American Iron and Steel Institute this year.

JOHN F. ELLIOTT

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## Northeast Radio Observatory Corporation/Haystack Observatory

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The Haystack Observatory is a research center engaged in radio astronomy, geodesy, atmospheric science, and instrumentation development for radiometry and radar systems. Parts of its programs are conducted under the auspices of the Northeast Radio Observatory Corporation (NEROC), a consortium of thirteen educational and research institutions\* in the northeast. During the past year, Tufts University joined the NEROC consortium. The Observatory receives financial support from the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the National Geodetic Survey (NGS), the National Radio Astronomy Observatory (NRAO), and the Department of the Air Force, directly and through the MIT/Lincoln Laboratory.

The main instrument at the Observatory, located at Westford, MA, is a 120-foot diameter paraboloidal antenna enclosed in a radome. It is heavily used by the astronomy community as a radio telescope with radiometers operating at 18-, 13-, 6-, 3.5-, 2.8-, 1.9-, 1.3-, and 0.7-cm wavelength. In the past year, the telescope was used by approximately 90 investigators from over 25 different national and international institutions, and 30 articles were published in scientific journals based upon this work. A conference titled "Masers, Molecules and Mass Outflows in Star Forming Regions" was hosted by the Observatory last year and was attended by over 100 astronomers from the international community. The proceedings of the conference were recently published.

The refurbishing and upgrading of the 150-foot radome that houses the Haystack antenna was completed this past year. Of the 930 panels in the radome, 773 were replaced with new ESSCOLAM-VI (TM) panels and an additional 67 ESSCOLAM older panels were refurbished and reinstalled. The corroded hardware that attaches the panels was replaced and high tensile strength bolts at the radome hubs were replaced with low corrosion material bolts. As a result, the new radome material provides superior radio frequency performance at short wavelengths, the leaks in the old fiberglass panels were eliminated and the new material has faster drying time after rain allowing more time for scientific observations.

An improved version of the 36-50 GHz (0.7 cm wavelength) maser amplifier receiver was installed on the antenna and allowed a sensitive search for excited state OH to be carried out at 36 GHz in the source W3(OH). The  $v=0, J=1-0$  transition of SiO at 43 GHz was also successfully studied in regions of young star formation. Key observations of the CS line at 49 GHz have recently been made with this new maser in several galactic and extragalactic radio sources that indicated the presence of high density gas. Haystack possesses a unique measurement sensitivity at this frequency amongst U. S. radio observatories and anticipates continued strong demand from the astronomy community for observations of this line in galactic and extragalactic regions.

Highlights of single antenna astronomy research in the past year in the 20-25 GHz band (1.3 cm) included the monitoring of the powerful water vapor maser source in Orion A which is an active region of star formation. Recently this source flared again but to an unprecedented level of about  $2 \times 10^7$  Jy. The degree of linear polarization decreased from 60% to 40% during this recent flare. In addition dark clouds (regions of high extinction) and high velocity mass outflow sources in our galaxy were studied using the inversion transitions of the  $\text{NH}_3$  molecule. These transitions, which are closely spaced in frequency and detectable using Haystack's high resolution spectrometer, require widely differing conditions for excitation and allow molecular cloud parameters such as temperature and density as well as dynamical information to be obtained. A correspondence is found in dark cloud regions between the occurrence of the  $\text{NH}_3$  molecule and the incidence of IRAS infrared sources.

Very Long Baseline Interferometry (VLBI) research in astronomy and geodesy remains a key activity at Haystack. In the VLBI technique, signals recorded from the same object simultaneously by several radio telescopes are brought together at a multi-station processor to perform aperture synthesis. Haystack is a keystone telescope in the US-European VLBI Network, and Haystack's Mark III Processor provides a major part of the world's processing capability for observations of weak sources and for polarization measurements. In the last twelve months, 35 astronomical programs from various institutions were correlated on the Haystack Processor, resulting in some notable achievements. Through VLBI observations of radio-bright binary star systems in our own galaxy, the unification of stellar (optical) and radio (extragalactic) reference frames has finally been achieved. Extension of VLBI mapping to less luminous, presumably more stable quasar cores, using the Mark III technique, revealed instead that they also

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\*Boston University, Brandeis University, Brown University, Dartmouth College, Harvard University, MIT, Polytechnic Institute of New York, Harvard-Smithsonian Center for Astrophysics, State University of New York at Stony Brook, Tufts University, University of Massachusetts, University of New Hampshire, and Yale University.

exhibit rapid internal motions similar to the bright "superluminal" quasars. Wide-bandwidth capabilities of the Mark III system were employed to record both right- and left-hand senses of polarized radiation as well, allowing VLBI techniques to map electric polarization on a milliarcsecond scale for the first time and trace the magnetic field within several galaxy and quasar cores. Specific modules for the "central engines" that power luminous, compact extragalactic radio quasars and galaxies can only be tested by higher and higher resolving power, imaging closer to the fundamental energy source. In 1986, the Mark III system's wide-bandwidth capability allowed a successful observation of galaxy 3C84's core at a frequency of 43 GHz, thus revealing its structure at an impressive 150-200 micro arcseconds size resolution.

Last year a RIDGE 32C microcomputer was added at Haystack for the purpose of radio mapping and image processing. Both VLBI algorithms and the National Radio Astronomy Observatory's imaging software packages have been implemented, and the first results from this new system were presented at the June 1986 meeting of the American Astronomical Society.

The application of VLBI to the field of geodesy is also providing exciting new results in the measurement of the relative motion of the plates that constitute the earth's surface. Haystack Observatory participates in these measurements by providing two of the antennas used for observations and by utilizing the sensitive MkIII data processing system, which permits the use of other very small transportable antennas for the measurement of regional crustal deformation and of medium sized fixed antennas for tectonic plate motion. A major VLBI measurement campaign, begun in 1984, to measure the velocities of several of the plates surrounding the Pacific Ocean has confirmed within one year the values obtained from the analysis of historic geological data spanning millions of years. For example, between Japan and Hawaii and between Japan and Kwajalein, Marshall Islands, the distance is decreasing at a rate of  $7 \pm 2$  cm/year. The geological rate is 9 cm/year. From the same series of measurements, the motion across the San Andreas Fault in California has been determined. The OVRO antenna on the east side of the fault shows no motion towards an antenna in Alaska while the antenna at Vandenberg Air Force Base on the west side of the fault is moving towards Alaska at  $7 \pm 1$  cm/year. This difference agrees closely with that expected from the plate tectonic model. Great stability is demonstrated for other baselines. A series of observations between antennas in Massachusetts and California, designed to probe atmospheric effects on VLBI measurements, has shown that the length is not changing and is repeatable to under a centimeter. The eight measurements of the 4000 km distance has a scatter of only 8 millimeters.

The Very Long Baseline Array (VLBA), being constructed under NSF sponsorship, consists of a 10-element VLBI array of 25 meter telescopes covering the continental USA, Hawaii, and Puerto Rico. Haystack is responsible for the development of the data acquisition and playback systems of the VLBA; this includes design and construction of a prototype of the digitization and high density recording sub-systems. The prototype data acquisition system is now nearly completed and will be tested along with other VLBA electronics in late 1986. In early 1987 the system will be installed at the first VLBA telescope now being constructed at Pie Town, New Mexico. The VLBA, which is under the direction of the National Radio Astronomy Observatory, will provide VLBI scientists, including those at the Haystack Observatory, with a powerful high resolution astronomical instrument.

Of great importance to both the current and future VLBI programs, including the VLBA, has been the development by Haystack engineers of a high density recording system which provides a factor of 12 reduction in the number of tapes required for VLBI experiments. During the past year the production of large numbers of these systems has begun, and field installation at several observatories was successfully completed. It is expected that most major radio observatories will be equipped with the density upgrade by the end of 1987. A second major engineering development at Haystack has been the redesign of the MkIII correlator in order to enhance its speed and capacity. A new correlator has been built and installed by Haystack at the U. S. Naval Observatory in Washington, D. C. during the past year to help process the large volume of geodetic VLBI data.

The 60-foot diameter Westford antenna, located one mile south of the Haystack antenna, was operated this past year as a dedicated geodetic VLBI station, as part of the IRIS (International Radio Interferometric Surveying) project. Absolute determination of the rotation rate or length of day (UT1) and of the point of intersection of the earth's axis and the crust (polar motion) is made at intervals of five days by observing for 24 hours continuously. Other regularly participating antennas are located in Ft. Davis (TX), Richmond (FL), Wettzell (Germany), and Onsala (Sweden). Over 330 separate observing sessions have been held to date. The IRIS measurement rms accuracy is about 0.1 msec in UT1 and 10 cm in polar motion, and VLBI is the most accurate and reliable technique for measuring these quantities. A series of daily, quick determinations of UT1 also yields accuracy of 0.1 msec in UT1 and has become a regular feature of the program. A very close correlation between estimates of atmospheric angular momentum and UT1 has been observed. Present observations are focused on watching for transient anomalies in UT1 which may occur with crustal adjustments associated with large earthquakes. A water vapor radiometer supplied by the NASA Crustal Dynamics Project has been installed at Westford to measure atmospheric propagation delay due to water vapor. It is hoped these measurements will aid in achieving continental baseline accuracies better than 1 cm.

The MIT/Haystack Atmospheric Sciences program uses the Millstone Hill UHF radars, with 220-foot zenith-fixed and 150-foot steerable antennas, for studies of the upper atmosphere, ionosphere, and magnetosphere. Millstone participates in an extensive World Day program which involves monthly collaborative observations with radar facilities in Peru, Puerto Rico, Greenland, France and Scandinavia. In the past year, detailed analysis of such a global measurement campaign, emphasizing the structure and dynamics of the earth's thermosphere, was completed, and a workshop was held at MIT in the summer to review the results with our international collaborators who operated other radars and optical instruments and with theoretical modelers of the upper atmosphere. In addition, the Millstone Hill facility has been upgraded to support a program of high-resolution, real-time, interactive ionospheric diagnostics. During the Spacelab 2 campaign last year, the Space Shuttle main engines were fired over Millstone Hill in an active experiment which created an ionospheric "hole" in order to study basic atmospheric plasma processes. Millstone Hill radar diagnostics were made available to the experimenters at NASA/Houston as they were taken so that experiment operations could be optimized. All Millstone Hill experiments can now be monitored remotely in real-time, greatly expanding the utility of these data. During the year, a second 2.5 MW transmitter was completed and fully integrated into the operating system. Selected experiments can now be run at a total peak transmitted power of 5 MW, significantly lowering the threshold of events and effects which can be studied. Finally, work has begun at the Observatory on a new group office and research facility building which will permit an enhanced level of student and visitor participation in the Atmospheric Sciences research program.

JOSEPH E. SALAH

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## Nuclear Reactor Laboratory

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During the past year the Nuclear Reactor Laboratory (NRL) engaged in joint activities with nine academic departments and interdepartmental laboratories, the Charles Stark Draper Laboratory, and 22 other universities and nonprofit research institutions, such as teaching hospitals. These joint research or teaching and training activities cover a wide spectrum in the life and physical sciences and in engineering, including neutron scattering studies of condensed matter, nuclear materials research and development, radiochemistry and trace analysis applied to health effects of coal use, nutrition studies, earth and planetary sciences, nuclear medicine, reactor engineering, computer control of reactors, and training in reactor operations.

### NEUTRON BEAM TUBE RESEARCH

The Neutron Diffraction Laboratory of Professor Clifford G. Shull in the Physics Department has continued to pursue experimental and theoretical studies of the fundamental wave properties of thermal neutrons and the diffraction physics of neutrons in crystals. A graduate thesis project involving a study of the spatial coherence of neutrons within a two-crystal interferometer was completed and the experimental observations were shown to be in agreement with computer calculations based upon a theoretical model. Further theoretical analysis was given to the anticipated existence of a Larmor Spin-Pendellösung resonance effect within crystals and based upon this, an experiment was designed for its study. This graduate thesis study involves the excitation of Pendellösung oscillation of diffracting neutrons in a perfect crystal of silicon and, at the same time, the generation of neutron spin rotation by Larmor precession in a uniform magnetic field. When the two periodicities are matched, resonant effects in the intensity released from the crystal are expected. Many of the preparatory details of the experiment have now been completed and results are expected at an early date. Such experiments are expected to lead to a new regime of measurement sensitivity for suspected spin-orbit interactions between neutrons and crystal atoms.

### NUCLEAR MATERIALS RESEARCH AND DEVELOPMENT

Alloy development activities for fusion reactor first wall materials continued for the eighth year under the direction of Professor Nicholas J. Grant (Department of Materials Science and Engineering) and Professor Otto K. Harling, Director of the Nuclear Reactor Laboratory. Professor Linn W. Hobbs (Department of Materials Science and Engineering) participated in the research, as did research scientists Dr. Janez Megusar and Dr. Gordon Kohse. A major thrust of this research effort has been the exploration of the use of innovative alloy processing techniques, such as rapid solidification from the melt, for the purpose of developing primary first wall alloys for fusion reactor first wall applications. The development of improved first wall alloys is on the critical path toward economical fusion power. The MIT approach provides a means to manipulate alloy microstructure and microchemistry in order to benefit irradiation performance. Alloy design, alloy production, irradiation testing, and postirradiation characterization are the major parts of this interdisciplinary project.

Most of the work during this project period involved microstructural and mechanical property characterization of specimens irradiated to significant damage levels at fusion-relevant temperatures. Important results were obtained on the behavior under neutron irradiation of 25 different copper and copper alloy materials, including a number of experimental rapidly solidified (RS) alloys produced at MIT. A master's thesis was completed in the area of swelling and conductivity determination for these alloys, and all the experimental research was completed for a Ph.D. dissertation on their microstructural characteristics. A number of alloys, particularly MIT-produced oxide dispersion stabilized RS materials, resisted swelling and exhibited stable mechanical properties and conductivity to 14 dpa at 400°C. In addition, work was completed to add to our understanding of the neutron irradiation response of RS titanium-modified austenitic stainless steels. The effect of varying titanium and carbon content and thermomechanical treatment of these alloys on their microstructures and evolution under irradiation was investigated. The results were compatible with a swelling suppression model proposed in earlier MIT work on this project.

An approach to subminiature mechanical property testing has been developed over the last five years at NRL. This approach involves use of specimens which are only 3 mm in diameter and about 0.3 mm thick. The methods of finite element analysis are utilized to extract useful mechanical property information from a bend test. A patent on this technique has recently been obtained.

A promising specimen geometry was developed for use in a miniature disk bend test for ductile-to-brittle transition temperature determination. Notched specimens 3 mm in diameter by 0.4 mm thick showed a transition from predominantly ductile to predominantly brittle fracture in high strain rate bend tests. Correlations to Charpy V-notch data are not yet conclusive, but correct scaling of transition behavior of various materials may be possible.

Papers were presented at the Second International Fusion Reactor Materials Conference (Chicago, April 13-17, 1986) in all these research areas.

#### RADIOCHEMISTRY AND TRACE ANALYSIS

Professor Frederick A. Frey, Department of Earth, Atmospheric and Planetary Sciences, and research collaborators utilize the MITR-II for neutron activation analysis (NAA) of geologic materials. The activation analysis laboratory operated by Professor Frey and Dr. Pillalamarri Ila was utilized by 10 graduate students doing thesis research in the Department of Earth, Atmospheric and Planetary Sciences and by visiting scientists from foreign countries and other New England universities. During the past year MIT-based research has focused on determining and understanding geochemical differences between lavas erupted in different geologic settings; e.g., the continental setting of northern China, the plate convergent setting of central Chile in the Andes, and the intraoceanic plate settings of Hawaii and Iceland.

During 1985-86 a major attempt was made to increase the utilization of NRL by making its neutron activation analysis facilities and expertise available to industry, other universities, private and governmental laboratories and hospitals in the area (as described in The MIT REPORT, May 1986). Research and/or service-oriented collaborations were established with several research laboratories, including GTE, Standard Oil Research Center, AT&T, Polaroid Corporation, GM Research Laboratories, Norton Company, Northeast Utilities, Harvard School of Public Health, New England Aquarium and Wheaton College.

Dr. Ilhan Olmez, who joined NRL last year, is working on the development of new techniques of medical diagnosis which are based on the determination of trace elements in different body fluids and tissues using NAA. Ongoing research carried out jointly with Rensselaer Polytechnic Institute has already shown significant variations of certain trace element concentrations between normal and cancerous tissues.

Dr. Olmez is also working with Massachusetts General Hospital (MGH) researchers on the trace element characterization of spinal cord fluid.

Research support has been provided to Professor Adel F. Sarofim and James Wei (Chemical Engineering), Professors Brian J. Evans and M. Gene Simmons (Earth, Atmospheric and Planetary Sciences), Professor Paul M. Newberne (Applied Biological Sciences), Dr. Osman S. Gebizlioglu (Mechanical Engineering), and Dr. Alan E. Walts (Chemistry).

Dr. Olmez has been actively engaged in a number of environmental research projects. Recently financial support has been obtained from Northeast Utilities, Connecticut, to apply a novel method in wastewater treatment facilities and underground water relations.

Meanwhile Dr. Morteza Janghorbani and his radiochemistry group at Boston University have continued their activities in the area of stable isotope applications in human studies and are using the MIT Reactor to activate samples and NRL counting equipment to analyze them.

An extraordinarily sensitive technique for trace analysis of biomolecules has been developed by Professor Alexander Varshavsky, Biology Department, in collaboration with several staff members of the NRL. This technique obviates some of the important problems associated with the use of radioactive tracers, e.g., radiation damage and low pool concentration. In the current development neutron activation is used to detect the biomolecules of interest after separation. A patent application is in preparation.

#### NUCLEAR MEDICINE

Neutron capture therapy for cancers is in principle a uniquely attractive method of using radiation to destroy tumor cells without significant damage to healthy cells. Boron neutron capture therapy (BNCT) research and testing has a long history at the MITR, going back to the middle 1950s. Currently interest in this technique has greatly increased due to the apparent successes of Dr. Hiroshi Hatanaka of Japan, who has now used this therapy on approximately 100 people. Dr. Hatanaka became acquainted with BNCT when he worked at MITR-I during the early trials. At the present time Professor Harling has arranged a collaboration with several senior staff from the Tufts-New England Medical Center. A pre-proposal leading to clinical trials in three years has been developed and has received favorable comment from the US Department of Energy (DOE). A formal proposal for clinical trials is in preparation.

#### RADIATION HEALTH PHYSICS

The NRL supports a new subdiscipline in the Nuclear Engineering Department, Radiation Health Physics, by providing relevant research opportunities and a specially designed laboratory/demonstration course. The Radiation Health Physics program is under the direction of Professor Harling. The program is designed to produce graduates who are well educated in nuclear engineering fundamentals as well as in the basics of radiation measurement, management, and protection. Basing this activity at the NRL is particularly appropriate since the MITR-II provides excellent opportunities to learn many aspects of this subfield in a



realistic environment. Support for graduate students has been obtained from the Institute of Nuclear Power Operations and from several nuclear utilities.

#### COMPUTER CONTROL OF REACTORS

Professor David D. Lanning, Nuclear Engineering Department (NED), and Dr. John A. Bernard of the NRL continued studies on the closed-loop, digital control of nuclear reactors during both steady-state and transient operation. Assistance was received from Professors Allan F. Henry, John E. Meyer, NED, and from Dr. John H. Hopps, Jr., of Charles Stark Draper Laboratory. A general set of control principles, based on reactivity constraints and intended for nonlinear conditions, has been deduced and experimentally demonstrated on the MIT Reactor. This approach is unique in that it is based on the general equations of reactor dynamics rather than measurements of specific response characteristics. This work, which is supported by the National Science Foundation (NSF), resulted in seven publications during the past year. The 'reactivity constraint approach' has been licensed by the United States Nuclear Regulatory Commission (NRC) for general use on the 5 MWt MIT Research Reactor. Closed-loop control experiments can be performed without a priori restrictions on the associated reactivity. The significance of this license approval is that 1) no other research reactor in the United States has such a broad approval for closed-loop control and 2) a precedent has been established for our approach regarding such control. This gives the reactivity constraint concept an enormous lead over competing ideas in the United States. The project resulted in four major accomplishments during the past year. First, an alternate formulation of the dynamic period equation was derived by Professor Henry. This alternate equation has the advantage that no approximations are required. Controllers based on this relation were developed and tested. Second, a rule-based controller using 'expert system' techniques was designed and successfully demonstrated. Third, techniques for reconfigurable control were developed and demonstrated experimentally. Fourth, a study was made of 'set-theoretic' control techniques as applied to reactor dynamics. A collaborative effort with the Charles Stark Draper Laboratory in the areas of signal validation, fault detection, and reconfigurable control was continued. This research resulted in one M.S. and two Ph.D. theses during the past year. Demonstrations of the technology are available by appointment.

#### DOSE REDUCTION IN NUCLEAR POWER REACTORS

A major interdisciplinary and interdepartmental research program designed to develop radiation dose reduction technology for the nuclear power industry has been worked out during the past year with the Empire State Electric Energy Research Corporation (ESEERCO) and the Electric Power Research Institute (EPRI). Funding at the level of \$2.5 million for four years is now available to support the program, the design phase of which has essentially commenced already, including one student thesis completed and a second well under way. Radiation fields in the primary cooling system of today's light water reactors are undesirable from a health viewpoint and have a significant negative impact on plant capacity factors by impeding maintenance tasks. The principal goal of the project will be to reduce the radiation fields to which workers are exposed. Studies of how these fields are built up and methods for minimizing them will be conducted with the aid of small-scale coolant circulation loops installed in the core of the MIT Reactor, designed to simulate (in separate loops) conditions that exist both in pressurized-water reactors and in boiling-water reactors. The formation, transport and deposition of corrosion products in the coolant will be characterized, and tests will be carried out to obtain information about optimized water chemistry, surface treatments, and other parameters. Principal investigators are Professor Harling and Professor Michael J. Driscoll, Department of Nuclear Engineering. Others already participating are Dr. Gordon Kohse and Dr. Ilhan Olmez of NRL, members of the MIT Reactor staff, Professors Ronald G. Ballinger, Asashi Kitamoto, and David D. Lanning of NED, Professor Ronald M. Latanision of the Department of Materials Science and Engineering, Dr. William Lindsay, an expert consultant in the field of reactor coolant corrosion studies, and a growing number of MIT students from the departments mentioned above. Three utilities - Public Service Electric & Gas, Duke Power and Boston Edison - have provided additional financial support. These projects will utilize the MIT reactor directly and provide much needed support for experimental research in nuclear engineering. It is expected that two to four graduate students will be involved in this project after the initial start-up period.

#### REACTOR IRRADIATIONS AND SERVICES FOR RESEARCH GROUPS OUTSIDE MIT

In nuclear medicine the development and/or continuing production of radioisotopes for use by researchers at hospitals and other universities included: 1) production of Cl-38 for Drs. Bernard Hoop and D. C. Johnson, of the Pulmonary Unit in the Department of Medicine, Massachusetts General Hospital, who continue their studies on control of ventilation through the regulation of chloride ions in the cerebrospinal fluid in a dog model, 2) production of Au-198 seeds for cancer therapy for Dr. Philip Cobb of the New England Deaconess Hospital for use there and in other area hospitals, 3) research activities by Professor Webster S. S. Jee's group at the University of Utah Radiobiology Laboratory using solid state fission fragment track detectors to study the distribution and transport of plutonium in animal models, 4) production of Dy-165 for Dr. Prasanna P. Venkatesan of Brigham and Women's Hospital for research studies in the treatment of arthritis, and for Gamma Diagnostic Laboratories in Attleboro Falls, Massachusetts, for development of the commercial Dy-165 radiopharmaceutical, 5) production of Pt-197 and Os-193 Mössbauer sources for the

Chemistry Department at Northeastern University to study the chemistry and structure of gold compounds, particularly those exhibiting anti-arthritis and anti-tumor activity, 6) use of the reactor by Cadema Medical Products, Inc., of Middletown, New York, to irradiate holmium for the production of holmium-166 for a feasibility study; nuclear medicine studies indicate that this isotope is desirable for radiation synovectomy for rheumatoid arthritis, and 7) assistance to Cadema Medical Products, Inc., in preclinical trials of radiation synovectomy.

In a number of other areas, also, reactor irradiations and services were performed for research groups outside MIT. Some of these represent new activities, while a number are continuations of previous research: 1) the irradiation of sulfur targets for the production of 12 Curies per week of P-32 to label proteins for use in biological research was continued; 2) the irradiation of melted Greenland ice specimens to determine by activation analysis the abundances of Na, Cl and other elements as a function of depth (age) for possible dating of global events; 3) Professor J. Christopher Hepburn and Rudolph Hon and 10 students of Boston College used NAA to determine trace elements in geological systems; 4) Dr. Robert Tiernan of GTE Sylvania, Inc., continued use of the reactor to study the effect of sodium diffusion through aluminum oxide on the performance of sodium vapor lamps; 5) Dr. Frank Pink from the same laboratory irradiated ceramic materials to determine the uranium and thorium content with solid state neutron track detectors, 6) additional irradiations were conducted for activation analysis of filter and oceanic sediments by Dr. A. Fleer and two research assistants at Woods Hole Oceanographic Institute; 7) Professor Paul E. Sokol, from the Harvard Department of Physics, used the dual crystal neutron spectrometer for studies of high energy inelastic neutron scattering from hydrogen absorbed on grafoil; 8) Dr. Randall Pfleuger of the Charles Stark Draper Laboratory irradiated solid state devices in the fast neutron flux facility; these irradiations were done to determine the "radiation hardness" of these devices in a 1 MeV equivalent neutron flux; 9) samples of aluminum oxide were irradiated for Dr. Forrest C. Burns at the U.S. Army Materials Technology Laboratory, Watertown, Massachusetts, to determine their elemental content by neutron activation analysis.

For education of the general public and students at all levels in local and other New England schools, the reactor staff provides lectures and tours periodically throughout the year. Several local universities incorporated reactor visits and experiments into their regular course curricula, as follows: 1) Northeastern University, Mechanical Engineering Department, Nuclear Engineering I, Course 02.236, 27 students, 8 visits; 2) Northeastern University, Physics Department, Course PHY 1555, 9 students, 1 visit; 3) University of Massachusetts, Harbor Campus, Department of Physics, Physics 697, 30 students, 13 visits.

Following last year's successful trials, an educational program to familiarize high school science teachers with the scientific, engineering, and medical uses of nuclear research reactors and to involve the teachers in typical applications and experiments, with a special lecture and demonstration by the MIT Radiation Protection Office, was continued. Seven classes (two four-hour days each) were held with very enthusiastic response from the 60 teachers who attended. A proposal has been submitted to the USDOE to continue and expand this program.

#### MIT RESEARCH REACTOR

The MIT Reactor completed its 27th year of operation, its 11th since the 1974-75 shutdown for upgrading and overhaul. During the past year it continued its usual Monday through Friday operating schedule at the design power level of 5 MW, averaging 75.3 hours per week at full power, holidays and scheduled maintenance periods included. Energy output for the MITR-II, as the upgraded reactor is now called, totaled 202,324 megawatt-hours at June 30, 1986. The MITR-I generated about the same number of MWH in the sixteen years from 1958 to 1974.

To summarize briefly the reactor utilization described in more detail above, it was well utilized during the year, although many more experiments and irradiations can be accommodated due to the number and versatility of its many facilities. The reactor, as an integrated whole, continues to be used in a series of experiments designed to demonstrate the feasibility and advantages of reactor control by digital computer. The neutron beam ports saw substantial utilization for neutron diffraction experiments, and the triple-axis spectrometer was refurbished to provide digital computer control of inelastic scattering experiments. The number of material specimen irradiations was over 5300, well above the average of recent years. Theses and publications on research supported by the reactor are running at about 14 and 50 per year, respectively. A major new interdepartmental project on dose reduction for power reactors was initiated with EPRI and ESEERCO support.

The US Department of Energy renewed its reactor-sharing grant whereby MIT is reimbursed for use of the Reactor by other educational institutions needing such a facility for teaching or research purposes. Nearly 200 students and 40 faculty and staff from 14 educational institutions (including teaching hospitals) benefited from visits and use of the MITR. These figures are in addition to the high school science teachers program mentioned above. Continuation of this funding has been granted for the coming year.

DOE is also supplier of fuel to university research and training reactors. Babcock and Wilcox (B&W), Lynchburg, Virginia, is the fabricator and is now in production on another batch of fuel for the MITR-II.

DOE is also funding an extensive development program under the direction of Argonne National Laboratory aimed at enabling research reactors to convert from high enriched uranium (HEU) fuel to low enriched uranium, and the MITR-II is committed to such a conversion when suitable fuel and supporting Federal funds become available. The provisions for the security of HEU fuel being used at the reactor in the meantime not only meet and exceed Nuclear Regulatory Commission requirements but have been the subject of a favorable report after being reviewed by cognizant officials of the City of Cambridge.

During 1985-86 a portion of the reactor costs were offset by a first-time grant from DOE in support of operation of the MITR-II. In connection with the generic question of such support for university reactors, DOE is initiating a study of whether the Federal Government provides adequate financial assistance for the operation of university research and training reactors and the research programs that reactors of the former type support. Federal funding falls far short of the assistance provided by DOE and NSF to a number of US universities for operation and utilization of particle accelerators; it is also much less than several European governments provide for support of their university class research reactors. In connection with this study, NRL is assisting DOE to accumulate detailed information regarding research reactor accomplishments.

OTTO K. HARLING

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## Operations Research Center

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The Operations Research Center (ORC) was established in 1953 to provide educational and research opportunities for students and faculty interested in the interdisciplinary field of operations research. The academic staff of the ORC is drawn from many departments, including the Sloan School of Management, Electrical Engineering and Computer Science, Civil Engineering, Aeronautics and Astronautics, Ocean Engineering, Urban Studies and Planning, and Mathematics. During 1985-86, the ORC was managed by Professor Jeremy F. Shapiro, one of the two codirectors, and a core of administrative staff. The other codirector, Richard C. Larson, was on sabbatical leave. More than 40 graduate students were enrolled in the PhD and master's degree programs, and 25 faculty were affiliated with the ORC during 1985-86.

Faculty and students at the ORC were engaged in a broad range of activities during the past year. Research was directed at numerous topics in mathematical programming, manufacturing systems, transportation and logistics, public sector applications, and applied queueing research, and models for analyzing competitive strategy were developed. In this report, we discuss briefly each of these areas and highlight the ORC's educational activities.

### RESEARCH ACTIVITIES

#### Mathematical Programming

Mathematical programming is the field concerned with methods for creating and solving constrained optimization problems. ORC faculty and students made theoretical contributions to the field in several areas.

Under National Science Foundation funding, research continued on network design and facilities location models. New results characterizing the underlying mathematical structure of the models were obtained, and new heuristic methods, based in part on these results, were developed. The objective of this research is the implementation of efficient algorithms for very large scale models arising in transportation and communication.

Research also continued in the development of new algorithmic approaches for network optimization and mixed integer programming models. The research was directed in part at new approximation and aggregation methods for quickly extracting good answers from difficult-to-solve models. The research sheds light on the nature of the computational complexity of these models and how this complexity varies within a family of closely related models.

New research began on models for stochastic programming with recourse. These are mathematical programming models that allow the explicit analysis of multiple scenarios for the future, each with an associated probability of occurrence. Optimizing the models produces contingency plans for each scenario and an optimal here-and-now strategy that hedges against the contingency plans. ORC research was directed at developing new constructive methods for defining and refining scenarios based on the probability distributions describing the uncertainties. These are iterative methods that take into account optimal solutions previously calculated for less refined approximate models. Applications of the techniques were made to multi-stage manufacturing planning and to fixed income portfolio selection.

Research was also begun on methods for solving large-scale mathematical programming models on parallel computers. Mathematical programming decomposition methods provide rigorous approaches for breaking large-scale models down into individual sub-models that can be analyzed by separate processors. Related research was begun on how best to adapt classical mathematical programming algorithms, such as the simplex method and branch-and-bound, for parallel computers. Research funding is being sought via proposals submitted in response to University Research Initiative requests for proposals from the Department of Defense.

#### Manufacturing Systems

International competition, changes in technology, and concerns about low productivity have caused managers to seek fresh approaches for controlling manufacturing systems. As a result, new opportunities have arisen for applying operations research models and methods to support manufacturing decision making. ORC faculty and students were involved in several projects concerned with production scheduling, the design and expansion of flexible manufacturing systems, job shop scheduling, manufacturing learning, and quality control. Techniques employed included queueing networks, mathematical programming, heuristics, and Monte Carlo simulation. The research was supported by grants from Draper Laboratories, IBM, MA/COM, and Bell Laboratories.

## Transportation and Logistics

Under a grant from United Parcel Service, research was performed on optimization models for route and facility planning. In particular, the problems addressed arise in point-to-point delivery systems, including mail delivery, less-than-truckload freight distribution, rail freight planning, and computer networking and communications systems planning (where communication packets play the role of trucks). A new decomposition approach for this problem was developed and is being extensively tested.

ORC faculty were involved in an applied logistics modeling project with a major industrial gases company. A large-scale model was designed and implemented for integrating regional manufacturing and distribution planning. The model allocates forecasted demand within the region and simultaneously determines manufacturing and distribution plans for each plant within the region, so as to minimize the total cost of meeting demand. The modeling system has proven highly successful and will soon be extended to a strategic planning model for analyzing the company's activities over the long term.

## Public Sector Applications

Operations research applications in the public sector were developed by ORC faculty and staff in the areas of criminal justice, urban services, and medical services. Under a grant from the National Institute of Justice, work continued on developing algorithms for computer-aided dispatch systems for police departments. These systems help "911" call-takers and police radio dispatchers to receive and quickly process calls for police service from the public. Applied modeling projects in medical services were undertaken to study budget allocation procedures for mental health care facilities and to optimize radiation treatments for cancer patients.

## Applied Research in Queueing

Research continued on a three-year grant from the National Science Foundation on analysis of queueing delays and their environments. This research is predicated on the hypothesis that the customer's actual and/or perceived cost of participating in a queueing-line service system are (1) a nonlinear function of the queueing delay and (2) multiattributed. The other attributes, in addition to queueing delay, reflect the customer's attitudes towards the queueing environment and the extent to which "social injustice" exists. New theoretical and empirical results are being developed, and it is hoped that these will describe customer behavior in the more complex situations more accurately than conventional models.

## Models for Analyzing Competitive Strategy

ORC faculty were involved in two separate research activities involving the development and analysis of operations research models to explain competitive strategy and to support a company's decision making in the face of competition. In marketing, new models were created to investigate how a new product should enter the market given that the existing products will defend their markets by lower price strategies. Related research was carried out to investigate how each one of multiple firms in a market should decide, from a competitive viewpoint, on promotions. In separate research, ORC faculty used game-theoretic optimal stopping models to analyze equilibrium entry and exit behavior in oligopolistic industries. On-going research is focused on how firms choose among different types of manufacturing technologies for their entry decisions.

## EDUCATIONAL PROGRAMS AND ACTIVITIES

The Operations Research Center offers two interdepartmental graduate degree programs, one leading to a PhD degree in operations research and the second leading to a master's degree. During 1985-86, 42 students were enrolled in these programs--27 PhD candidates and 17 SM candidates. Twelve master's degrees and six PhD degrees in operations research were conferred during 1985-86.

Students in the Operations Research Center represent a variety of backgrounds and countries. Nearly 50 percent of ORC students were from foreign countries; 35 percent of the students were women, a higher percentage than in any prior year. ORC students have attained considerable scholastic achievement, as evidenced by the number of fellowships and scholarship holders among them: several students held scholarships from their respective countries; six students held Charles Stark Draper Fellowships. Other students have received departmental teaching awards.

This year, as part of an ongoing effort to improve the quality of the educational and research programs undertaken by the ORC, Associate Provost and Vice President for Research, Kenneth A. Smith, initiated a review of the Operations Research Center. Professor Smith struck a committee consisting of six ORC-affiliated faculty and chaired by Professor Thomas L. Magnanti. The committee conducted interviews with administrative and academic staff connected with the operations research community both at MIT and at other universities. It also conducted surveys of ORC students, faculty, and alumni on factors relating to the educational experience at MIT. The results were summarized in a report submitted to Professor Smith in May 1986.

The Operations Research Center regularly offers professional courses during the Summer Session. In the summer of 1985, three such programs were offered--"Decision Analysis: Basic Concepts and Applications"; "Decision Analysis with Multiple Objectives: Concepts and Applications"; and a new course, "Operations Management in the Service Industries."

The ORC Seminar Series was privileged to have speakers from business and industry as well as from academia this year. Among the operations research professionals who made presentations, we had Ellis L. Johnson from IBM Watson Research Center, Yorktown Heights, New York; Eva Tardos from the Mathematical Science Research Institute, Berkeley, California; Richard Hildebrand from the Charles Stark Draper Laboratory; J. Michael Harrison from Stanford University; and Ludo Van der Heyden from Yale University.

Jeremy F. Shapiro

During the past year, technical progress has been made in all Plasma Fusion Center (PFC) research programs. The Plasma Fusion Center is recognized as one of the leading university research laboratories in the physics and engineering aspects of magnetic confinement fusion. Its research programs have produced significant results on four fronts: (a) the basic physics of high-temperature plasmas (plasma theory, rf heating, free electron lasers, development of advanced diagnostics and small-scale experiments on the Versator tokamak and Constance mirror devices), (b) major confinement results on the Alcator C tokamak, including pioneering investigations of the stability, heating, and confinement properties of plasmas at high densities, temperatures and magnetic fields, (c) development of an innovative design for axisymmetric tandem mirrors with inboard thermal barriers, with encouraging results from the initial phase of operation of the TARA tandem mirror experiment, and (d) a broad program of fusion technology and engineering development that addresses problems in several critical subsystem areas (e.g., magnet systems, superconducting materials development, environmental and safety studies, advanced millimeter wave source development, and system studies of fusion reactor design, operation, and technology requirements). The Plasma Fusion Center technical programs are principally supported by the Department of Energy's Office of Fusion Energy. During the past year, the funding level has been approximately \$26 million. There are approximately 300 personnel associated with PFC research activities. These include: 24 faculty and senior academic staff, 61 graduate students and 14 undergraduate students, with participating faculty and students from Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics; 106 research scientists and engineers and 11 visiting scientists; 52 technical support personnel; and 35 administrative and support staff.

### ALCATOR CONFINEMENT EXPERIMENTS

The primary objective of the Alcator experimental program, headed by Ronald Parker, is to develop the basic physics understanding of the stability, transport and radiation properties of high-temperature tokamak plasmas at near-reactor conditions and to develop radio-frequency methods for heating and driving currents in plasmas at thermonuclear temperatures. The main Alcator experimental areas include: device operations (David Gwinn); confinement studies (Stephen Wolfe); plasma-wall interactions (Earl Marmar); radio-frequency heating (Miklos Porkolab); data acquisition and computations (Martin Greenwald); and toroidal analysis (Dieter Sigmar). Professors Ronald Parker and Bruno Coppi are principal investigators of the overall Alcator program.

Work is continuing under the direction of Bruce Montgomery and Ronald Parker on the design of Alcator C-MOD, a follow-up device to Alcator C. Alcator C-MOD would provide useful supporting data for a high-field tokamak ignition experiment, and contribute to advanced tokamak concepts in the areas of stability and auxiliary heating and noninductive current drive techniques.

Ohmic Confinement Studies: Detailed analysis of pellet fueling experiments carried out in 1985 has confirmed the reduction of ion thermal transport to neoclassical levels. The experiments suggest that the anomalous losses observed in gas-fueled discharges may be related to " $\eta_i$ -mode" turbulence, which is theoretically predicted for large values of the profile parameter  $\eta_i \equiv d\ln T_i / d\ln n_i$ . Further investigations indicate that particle transport, as determined by an analysis of the intrinsic and extrinsic impurities, is comparable to neoclassical predictions following pellet injection.

Rf Heating and Current Drive: Ion cyclotron heating experiments have been carried out using both fast-wave launching and ion-Bernstein-wave launching in the Alcator C tokamak for densities in the range  $0.7 \times 10^{14} \text{ cm}^{-3} < n_e < 3 \times 10^{14} \text{ cm}^{-3}$  and toroidal magnetic fields in the range 6-12 tesla. Fast-wave heating experiments resulted in ion temperature increases of  $\Delta T_i \sim 100 \text{ eV}$  at input powers of 300 kW, plasma densities of  $n_e \sim 3 \times 10^{14} \text{ cm}^{-3}$ , and wave frequencies corresponding to  $\omega = 2\omega_{CH}$  (hydrogen majority) as well as  $\omega = \omega_{CH}$  (minority) in a deuterium majority plasma. A new antenna with an improved wavenumber spectrum is being fabricated to improve the heating efficiency and will be tested during the summer of 1986.

Ion Bernstein wave heating (IBWH) is being tested both at a majority species odd-harmonic resonance ( $\omega/\omega_{CH} = 3/2$ ) and for minority absorption ( $\omega/\omega_{CD} = 3$ ,  $\omega/\omega_{CD} = 5/2$ ) in a hydrogen majority plasma. During ion Bernstein wave injection, an increase in the bulk ion temperature and an increase in the particle confinement time are observed. Strong ion heating is observed in the density range  $0.7 \times 10^{14} \text{ cm}^{-3} < n_e < 1.5 \times 10^{14} \text{ cm}^{-3}$  where  $T_H = 0.9 \text{ keV}$  and  $T_e = 1.8 \text{ keV}$  initially, and  $\Delta T_H \sim 350 \text{ eV}$  for  $P_{RF} \gtrsim 170 \text{ kW}$ . The observed increase in the particle confinement time implies a reduction in the ion energy convection loss which in itself could explain some of the observed ion heating. A nonthermal ion distribution is also observed on the minority (typically deuterium) ion species ( $T_D \sim 2.5 \text{ keV}$ ) which cannot be explained by improved particle confinement alone. We conclude that a fraction of the applied rf power is propagating to and absorbed at the plasma center near either the  $\omega = 3/2\omega_{CH} = 3\omega_{CD}$  resonance layer or the  $\omega = 5/2\omega_{CD}$

resonance layer. The remainder of the applied rf power may be absorbed at the plasma edge near either the  $\omega = 2\omega_{CD}$  or the  $\omega = 3\omega_{CD}$  layer, respectively. Collective  $CO_2$  laser scattering is also used to detect the propagation and absorption regions of the ion Bernstein waves and the data are used to interpret the above results.

In another series of experiments, stabilization of the "sawtooth" oscillation near the plasma center by means of noninductive current drive is being investigated. Traveling lower hybrid waves (4.6 GHz) are launched so as to generate off-axis current. The sawtooth instability is suppressed when the rf-driven current is in the same direction as the inductively maintained ohmic current.

Alcator C-MOD: A Proposed Modification to the Alcator C Facility: The success of Alcator C in achieving a Lawson parameter in excess of that required for breakeven at higher temperatures has underscored the value of the high-field, high-density tokamak. Present plans for a near-term ignition experiment (Compact Ignition Tokamak) focus on this approach as the most promising and economical means of exploring fundamental issues associated with the physics of burning plasmas. The Alcator C-MOD facility is proposed as an upgrade to Alcator C aimed at investigating the characteristics of high-temperature, ICRF-heated plasmas, with the goal of understanding the physics of rf heating, confinement, stability, impurity control, fueling, and shaping of high-performance tokamaks. A primary motivation for Alcator C-MOD is to serve as an integrated test facility for addressing key physics issues related to successful operation of the CIT.

Alcator C-MOD will feature a major radius of about 64 cm, the same as Alcator C, with an aspect ratio of 3 and plasma elongations up to 1.8. The toroidal field capability will approach 10 tesla, less than the design field of Alcator C but permitting plasma currents up to 3 MA (compared to 0.8 MA in Alcator C) and plasma densities above  $5 \times 10^{14} \text{ cm}^{-3}$ . The principal qualitative improvements over Alcator C, besides the elongated, D-shaped cross section, include greatly increased access for rf heating, power removal, improved diagnostics, and a partially closed divertor configuration for impurity control and possible confinement enhancement (H-mode). The design provides for approximately 6 MW of rf heating in the ion cyclotron frequency range. Advanced shaping capabilities (indented "crescent" shape), the development of the physics and technology of electron cyclotron heating, the investigation of methods for operating in the second-stability regime, and the development of efficient methods of current drive are options being considered for Alcator C-MOD. These will enhance significantly its potential contributions to the development of the tokamak confinement concept for fusion reactor applications.

#### MIRROR CONFINEMENT EXPERIMENTS

The Mirror Confinement Experiments Division, headed by Richard S. Post, is involved in the operation of the medium-scale TARA tandem mirror research facility. With the completion of the experimental facility and the initiation of experiments, TARA represents a major step forward within the national fusion program. The primary objective of TARA operation during the past year was rf start-up, thermal barrier formation and MHD stability analysis. In the longer term, experimental studies will include micro-stability properties, alternative potential enhancement schemes and new stability concept evaluation. The main areas of activity include: program management (John Tarrh); TARA operations and power engineering (Marcel Gaudreau); experimental and rf systems (Don Smith); and computations and advanced concepts (Jay Kesner).

TARA Tandem Mirror Experiment: The TARA device is currently in its third year of operation. Experiments were resumed in April, 1985, after a six-month period during which the TARA device and systems were significantly upgraded. In addition to the installation of a 6 MW neutral beam system, which essentially completes the major part of TARA construction, new diagnostics and heating and fueling systems were added to the central cell and axisymmetric plug. Preliminary experiments with the new TARA configuration indicate improved plasma performance in the central cell and plug parameters appropriate for successful neutral beam injection experiments, which began in August, 1985.

The TARA tandem mirror consists of a 10 m solenoidal cell bounded by axisymmetric confining plugs and an outboard minimum magnetic field MHD anchor. The configuration was designed to minimize radial particle transport arising from the net radial drifts of ions bouncing in an azimuthally asymmetric field. The major physics objectives of TARA are to investigate plasma stability, central cell radial transport, and the formation of enhanced potential barriers in the plugs to control ion and electron axial transport.

Past experiments on TARA have focused on optimization of the central cell and anchor parameters. Based on data obtained during 1984, the central cell heating and fueling systems were redesigned to reduce hot ion loss due to charge-exchange recombination with cold neutral hydrogen, and to limit the flux of neutral gas into the plug, where it would be expected to interfere with neutral beam buildup of the plasma. Greatly improved gas use has been achieved with the new fueling system and the neutral gas pressure in the plug is now sufficiently low for neutral beam operation. TARA central cell plasma parameters are continually being improved. With 400 kW of ICRF power, the ion temperature is on the order of 400 eV, the density is  $\sim 4 \times 10^{12} \text{ cm}^{-3}$ , and the plasma beta is  $\sim 1\%$ . The energy confinement time has tripled in recent operation.



Two 18 GHz klystrons have been installed in the anchors, increasing the electron cyclotron heating (ECH) power and allowing hot electron beta values greater than 15% to be obtained. One of the main issues to be resolved is the stabilizing influence of hot electron beta and hot ion beta (produced by ICRF) in the anchor on the central cell and plug plasma curvature-driven modes. The two neutral beam sets, which consist of three sources per set, have been operated successfully, producing the so-called "sloshing ion" distribution necessary for electrostatic potential barrier formation. Four 28 GHz, 200 kW gyrotrons, purchased from Varian Associates, Inc., provide electron cyclotron heating in each plug in order to enhance the ion-confining potential barrier. In early operation of these systems, the central endloss was reduced through end plugging at a density of  $10^{12} \text{ cm}^{-3}$ .

Computations and Advanced Concepts: The TARA research program has a combined theoretical and experimental effort which permits a close collaboration between experiment, theory, computation, and reactor design. Areas of emphasis include low-frequency stability (trapped-particle and MHD theory), micro-stability, and rf heating theory, as well as the development of promising new magnetic geometries. In order to gain a better understanding of results from the axicell gyrotron heating experiments, the theory of hot-electron interchange modes has been pursued. In addition, in collaboration with the Institute for Fusion Studies (University of Texas, Austin), the formalism for a variational quadratic form has been developed suitable for the analysis of low-frequency, fully electromagnetic perturbations.

A major technical advance in tandem mirror design, the magnetic limiter, has been developed for TARA and will be installed during July, 1986. The magnetic limiter will stabilize the  $m = 1$  mode, the only unstable mode observed in TARA, and permit halo plasma formation. This halo plasma serves to shield the plasma from neutral gas and impurities. If these experiments are successful, tandem mirrors will be simpler and less expensive to build. The concept will also have application to several other confinement devices.

#### APPLIED PLASMA PHYSICS RESEARCH

The primary objective of the Plasma Fusion Center Applied Plasma Physics Research Division, headed by Ronald Davidson, is to develop the basic experimental and theoretical understanding of plasma heating and confinement properties. Present applied plasma physics research activities include: experimental research on the Versator II tokamak (George Bekefi, Miklos Porkolab and Stan Luckhardt); experimental research on the Constance B mirror device (Richard Post and Donna Smatlak); fusion theory and computations (Abraham Bers, Bruno Coppi, Ronald Davidson, Thomas Dupree, Jeffrey Freidberg, Jay Kesner, Kim Molvig, and Dieter Sigmar); spin-polarized fuel source development (Thomas Greytak and Daniel Kleppner); plasma diagnostics and laser development (Daniel Cohn and Paul Woskoboinikow); and space plasma theoretical research (Kim Molvig).

The progress made during the past year in selected applied plasma physics research areas is summarized below.

Versator II is a medium-sized research tokamak (major radius = 40.5 cm, minor radius = 13 cm, toroidal field = 15 kG) with primary emphasis on basic investigations of rf plasma heating and current drive. Significant progress has been made in the past year in several experiments which have taken advantage of the newly upgraded capability of Versator II including the ability to study fully rf-driven plasmas without ohmic heating.

A universal feature of lower-hybrid current drive experiments to date has been a "density limit." Efficient lower-hybrid current drive appears to be possible only when  $\omega/\omega_{\text{LH}} > 2$  where  $\omega_{\text{LH}}$  is the lower-hybrid resonance frequency. In previous 800 MHz experiments on Versator II this limit occurred at a density of  $\bar{n}_e = 6 \times 10^{12} \text{ cm}^{-3}$ . In the present experiments, a new 100 kW rf system operating at 2.45 GHz is being used to study the frequency dependence of the density limit. With the new system, fully rf-driven plasmas have been achieved at densities as high as  $\bar{n}_e = 1 \times 10^{13} \text{ cm}^{-3}$ , substantially exceeding the 800 MHz density limit, and current drive effects are observed up to  $\bar{n}_e = 2.5 \times 10^{13} \text{ cm}^{-3}$ . The experiments have clarified several physics issues that have been a subject of intense scientific debate regarding mechanisms for rf current drive. In order to better understand the physics of lower-hybrid wave propagation, a microwave scattering diagnostic was used to detect directly the externally launched 800 MHz lower-hybrid waves in the current-drive regime. In conjunction with the current drive studies, it has also been shown that combined inductive-ohmic and lower-hybrid current drive improve the particle confinement time,  $\tau_p$ , by a factor of 2 above the case without rf power. This improved confinement behavior is found to occur in both the 800 MHz and 2.45 GHz experiments, and the physical mechanism responsible for the improvement is presently under study.

In 1985, construction of a new 100 kW, 35 GHz electron cyclotron resonance heating (ECRH) system began. These experiments will test heating and current-drive processes using combined rf power near the lower-hybrid frequency and the electron cyclotron frequency. The experiments are expected to begin in late 1986, and should result in improved current-drive efficiency. A second, combined current-drive experiment is in the planning stage, which will employ 800 MHz fast lower-hybrid waves in conjunction with 2.45 GHz slow waves. Again, the combined experiment should improve the overall current-drive efficiency.

To launch the fast wave in Versator II, a dielectrically loaded ( $\text{TiO}_2$ ,  $\epsilon = 80$ ), phased-waveguide-array structure has been designed and is being fabricated by industry. This experiment is expected to become operational later in 1986.

Constance B: Constance B is a quadrupole mirror device of moderate size in which high-beta, hot-electron plasmas are created using electron cyclotron resonance heating (ECRH). The major objective of the Constance program is to contribute to the basic physics understanding of the equilibrium and stability properties of mirror-confined hot-electron plasmas. Investigations of radial potential control and ion transport in hot electron plasmas are also a fundamental part of the Constance B research program.

The study of stable, long-pulse, high-beta equilibria is an essential aspect of the development of novel confinement schemes. Recent evidence suggests that the equilibrium pressure distribution in Constance B is peaked off axis and follows a curve the shape of a baseball seam. This configuration is stable over fractions of a second although it should be unstable according to MHD theory. The baseball-seam curve is the drift surface of the deeply trapped hot electrons.

Understanding hot-electron microinstabilities is also important for the development of the thermal barrier, a means to increase the plasma confinement in tandem mirrors. One of the microinstabilities which is observed in Constance B has been identified as the electron whistler instability. This instability has been found to be driven by the warm electrons (1-3 keV), while the hot electrons are observed to be microstable. The results of these experiments suggest that the electron whistler instability will not be a limiting factor in the performance of tandem mirror reactors as had been previously believed.

The long confinement times, high energies, and densities which are characteristic of the hot electrons in Constance B present ideal conditions for the generation of highly stripped ions. As part of an effort to broaden the scope of the Constance B program we are investigating the potential of the device for application to ion sources. Methods of selectively enhancing the production of a particular charge state using ICH will be addressed. Calculations have indicated that helium-like argon will be present in the plasma, and experiments to measure the charge state in xenon plasmas will be carried out in collaboration with Lawrence Livermore National Laboratory.

In plasma theory and computations there have been major technical advances in several areas of research. These areas include: (a) electron heating and transport by ICRH waves in tokamak plasmas; (b) strong absorption in mode conversion for ion heating; (c) efficiency and transport in lower hybrid current drive; (d) investigations of two-dimensional kinetic plasma turbulence; (e) theory of MHD clumps; (f) axisymmetric, kink and ballooning mode stability of advanced shaped tokamak plasmas; (g) effect of energetic trapped alpha particles on ballooning modes; (h) theory of alpha-particle effects in ignited tokamak plasmas; (i) transport theory of impurities in Alcator C and the effect on sawtooth oscillations; (j) ion loss-cone instabilities in tandem mirrors; (k) stabilization of the  $m = 1$  MHD mode by means of a magnetic limiter; (l) advanced tandem mirror configurations such as the DRAKON; (m) theory of free electron lasers including the development of advanced concepts, studies of harmonic generation, and nonlinear models for saturation and efficiency enhancement; and (n) theoretical studies of the nonlinear evolution of the electron whistler instability in magnetospheric plasmas.

#### FUSION TECHNOLOGY AND ENGINEERING

The Fusion Technology and Engineering Division, headed by Bruce Montgomery, provides critical engineering analysis for advanced design projects, and develops advanced superconducting and high-field copper magnet technology for the national fusion program. The areas of research during 1985-86 include: engineering design support for the proposed Alcator C-MOD tokamak (Bruce Montgomery); studies of advanced poloidal and toroidal field magnets and cryogenics for the Compact Ignition Tokamak (CIT) and the International Tokamak Reactor (INTOR) study program (Richard Thome, Robert Pillsbury and Joel Schultz); concept development for improved magnetic divertors for tokamak and mirror upgrades and next-generation test reactors (Ted Yang); development of internally-cooled, cabled superconductors for use in advanced fusion devices (Mitchell Hoenig); basic research on high-field, ductile superconductors (Simon Foner); and advanced magnet and conductor design in support of MHD and high energy physics projects (Peter Marston and John Tarrh). Recent progress in selected technology and engineering areas is summarized below.

The Alcator C-MOD device, a high-field tokamak proposed to be built at MIT in 1986-89, will test radio-frequency heating of the high-density plasmas that are prototypical of the conditions in a compact ignition experiment. The Alcator C-MOD design features cryogenically cooled magnets, a demountable toroidal field magnet, a single-piece vacuum vessel, and a poloidal divertor. The toroidal field coils for Alcator C-MOD feature sliding joints which require innovative engineering design and tests to ensure design reliability.

The Compact Ignition Tokamak (CIT) configuration was chosen by the national Ignition Tokamak Advisory Committee (ITOC) as a copper, high-field ignition device which would incorporate the best features of the IGNITOR, LITE and ISP designs studied in 1985. Bruce Montgomery is serving as Deputy Project Manager for Engineering for this national program, and Richard Thome is manager for the poloidal field system. The

CIT will require special laminated Inconel/copper plate for fabrication of the central solenoid and toroidal field coils. Practical bonding methods for these laminates are being developed for both CIT and Alcator C-MOD. Initial tests on laminates have shown that the face compression yield strength is more than doubled by the high-strength facings of Inconel, thereby making it possible for the conductors to resist the large, magnetically-induced stresses.

The finite-element codes for transient electromagnetics have been extended to allow evaluation of the coupled electromagnetic/thermal diffusion effects in the CIT design. The effects of structural steel laminated with copper have been included. In addition, modifications have been made to model a voltage-driven power supply (rather than the previous current-driven supplies). These modifications allow rapid evaluation of designs from the standpoints of thermal, energy and power requirements. A version of the electromagnetic code has also been modified to allow the inclusion of moving conducting media. Design and analysis tools for the poloidal field (PF) system for CIT have also been extended. These tools allow the rapid evaluation of candidate PF designs in terms of system parameters such as ampere-meters, stored energy, and peak power requirements, and in terms of individual coil parameters such as temperature, voltage, and average stress.

The divertor development group has been active in developing innovative particle control and modular tokamak and magnetic systems. A long-burning fusion reactor must deal effectively with removal of helium "ash" and impurities; magnetic or mechanical divertors are considered to be an extremely demanding but necessary component. An innovative method of recycling plasma ions back into the plasma core from the boundary has been proposed and studied analytically during the past year. An experimental study is in progress. This method will both clean the plasma and enhance beam heating. The divertor development group is also developing an innovative approach to integrating tokamak magnets. The tokamak's magnetic system consists of toroidal, poloidal and ohmic heating coils which have to share limited space. The space restrictions severely limit the performance of the ohmic heating (OH) coils and also limit system maintenance. A new concept is being evaluated which would build the toroidal field (TF) and OH coils as single units with the PF coils as loops. This permits fabrication of an integrated modular set of OH, TF and PF coils. This method will improve OH coil performance and increase system maintainability.

The principal task involving the use of internally-cooled, cabled superconductors (ICCS) is the design of the Multipurpose Coil (MPC) which is a subscale prototype of the central solenoid (ohmic heating) coils for fusion reactors. This task is multifaceted. It involves several collaborative efforts including: conductor sheath development in conjunction with Professor R. Ballinger in Materials Science and Engineering; the development of reliable commercial Nb<sub>3</sub>Sn superconductor with US wire vendors, with subprograms to develop optimized low-AC-loss conductor in quantities suitable for reactor use; the reactivation of an industrial tube mill for sheathing full-scale conductor; and, a program with the Naka Fusion Research Institute of the Japanese Atomic Energy Research Institute which will allow a prototype double pancake of the type to be used for the outer coil of the MPC to be tested before the coil design is finalized. Conductor tests are being performed in conjunction with the Lawrence Livermore National Laboratory (LLNL) which is responsible for the design and construction of the inner coil of the MPC. Tensile tests are now under way at that facility. As part of this collaboration, a 40 kA power supply was provided by MIT to make such testing possible.

Development of high-field Nb<sub>3</sub>Sn and Nb-Al superconductors using powder metallurgical techniques has continued. Focus has been on small-scale hydrostatic extrusion processing and on extending practical processing technologies. Exploration of mechanical alloying and rapid quenching has been initiated for Nb-Al. Depending on heat treatment, J<sub>c</sub> values for Nb-Al of up to 10<sup>4</sup> A/cm<sup>2</sup> at 19 T were achieved. This is a factor of 10 increase in J<sub>c</sub> since the last reported results.

The principal goal of MHD magnet design has been the development of a high-current conductor for large-scale MHD magnets based on the internally cooled, cabled superconductor design. To ensure that the conductor under development will meet the requirements of early commercial MHD magnets, an analytical and design effort has been performed on a preconceptual magnet based on input from the MHD community. This effort has allowed the preparation of a preliminary draft of the design requirements for an ICCS for commercial superconducting MHD magnets, and the initiation of subscale conductor testing.

Contributions to the high energy physics program have included an important role in assessing superconducting supercollider magnet system designs (Peter Marston), spectrometer design for the Continuous Electron Beam Accelerator Facility's toroidal large-acceptance detector, and continued involvement with the G-2 detector for an experiment at Brookhaven National Laboratory. The G-2 will measure, with precision heretofore impossible, the anomalous magnetic moment of the muon.

## FUSION SYSTEMS

The Fusion Systems Division, headed by Daniel Cohn, investigates several aspects of fusion reactor design and develops advanced diagnostics. Research activities include: reactor design studies (Leslie Bromberg, Daniel Cohn and John Williams); safety and environmental studies (Mujid Kazimi); and advanced diagnostic development (Richard Petrasso and Paul Woskoboinikow). Selected technical advances are summarized below.

Safety and Environmental Studies: An improved code has been developed to investigate possible fires in fusion reactors. In addition, reactor design implications of advanced fuels (deuterium and deuterium-helium three-fuel mixtures) are being studied. These fuels could provide significant advantages in safety and environmental features. Finally, new techniques are being developed to study disruptions.

Reactor Design Studies: The design concept for a compact ignition test experiment - LITE (Long Pulse Ignited Test Experiment) has been reduced in size to reduce cost. Engineering feasibility has been shown for a relatively simple design that uses strong, self-supported plate magnets made of beryllium copper or explosively bonded copper/Inconel. The explosively bonded copper/Inconel has been analyzed in terms of load sharing and a material development program has been initiated. The national ignition experiment design - CIT (Compact Ignition Tokamak) uses essentially all of the design features of LITE, differing principally in the utilization of a press to reduce stress in the magnet.

Advanced Diagnostics: X-ray imaging techniques are being developed to provide spatial and temporal measurements of various charged states of impurities in tokamak plasmas. A system is being constructed for use on the TEXT tokamak at the University of Texas. In addition, x-ray measurements of impurity transport in the Alcator tokamak have been made. These measurements were analyzed in terms of a theoretical model, resulting in important new insights regarding the transport processes.

A 140 GHz gyrotron has been constructed for scattering measurements from collective oscillations in the TARA tandem mirror experiment. The development of this gyrotron has extended the state-of-the-art capability in terms of its excellent spatial mode quality and narrow linewidth. After measurements are completed on TARA, the gyrotron scattering approach may be extended to develop techniques for measurement of alpha particles in an ignited tokamak plasma.

#### COHERENT ELECTROMAGNETIC WAVE GENERATION

In January, 1986, a new Division on Coherent Electromagnetic Wave Generation was established in the Plasma Fusion Center. This Division is headed by George Bekefi and Richard Temkin. Its primary objective is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in the 1  $\mu$ m to 1 cm range. Particular emphasis is placed on the development of free electron lasers, gyrotrons and novel radiation sources. A second area of research (Ron Davidson) relates to theoretical studies of the basic equilibrium and stability properties of nonneutral plasmas and intense charged particle beams, with applications to high-current accelerators and nonneutral electron flow in high-voltage diodes. A third area of research relates to basic theoretical and experimental investigations of laser-pumped, far infrared molecular gas lasers, including studies of laser tuning and efficiency. A fourth area of research is the relativistic magnetron, including studies of phase locking of magnetrons operating at high peak power.

In the area of free electron lasers, studies are underway concerning efficiency enhancement by means of tapering the wiggler period and/or amplitude. In addition, we are studying various innovative wiggler configurations. Two such systems are under active investigation. One comprises a circular wiggler in which a rotating electron ring is surrounded by an assembly of samarium-cobalt magnets. The other concerns the design and construction of a microwiggler with periodicity less than 1 cm. This system includes a standing electromagnetic wave trapped in the resonance cavity and energized by a high-power millimeter wavelength gyrotron. In gyrotron research, studies are underway of megawatt-power-level gyrotrons at a frequency of 140 GHz. Devices under test at short pulse lengths can be developed by industry into long-pulse tubes for plasma heating. The gyroklystron, a multiple-cavity gyrotron amplifier, is also being investigated.

#### APPOINTMENTS AND PROMOTIONS

During the past year, there have been several important appointments and promotions in Plasma Fusion Center program areas.

Appointments include: Dr. Paul Bonoli (MIT Research Laboratory of Electronics), appointed theoretical Research Scientist in the Toroidal Confinement Experiments Division; Dr. Jeffrey Casey (University of Colorado, Boulder), appointed experimental Research Scientist in the Mirror Confinement Experiments Division; Dr. Eric Esarey (Massachusetts Institute of Technology), appointed Postdoctoral Research Scientist in the Applied Plasma Physics Research Division; Richard Hale (MIT Francis Bitter National Magnet Laboratory), appointed Sponsored Research Technical Staff in the Fusion Technology and Engineering Division; Richard O'Connor (R.F. Communications, Inc.), appointed Technical Supervisor in the Mirror Confinement Experiments Division; Dr. Jesus Ramos (MIT Research Laboratory of Electronics), appointed theoretical Research Scientist in the Toroidal Confinement Experiments Division; and William Stein (Astral Wilcon, Inc.), appointed Technical Supervisor in the Mirror Confinement Experiments Division.

During the past year, promotions in the Plasma Fusion Center have included: William Beck, promoted to Sponsored Research Staff-Technical Assistant in the Toroidal Confinement Experiments Division; Eric Georgelis, promoted to Design Engineer in the Mirror Confinement Experiments Division; Dr. James Irby,

promoted to Project Leader for Diagnostics and Data Acquisition in the Mirror Confinement Experiments Division; William Parkin, promoted to Sponsored Research Staff-Technical Assistant in the Toroidal Confinement Experiments Division; Alexander Rabasco, promoted to Design Supervisor in the Mirror Confinement Experiments Division; Richard Ramirez, promoted to Sponsored Research Technical Staff in the Mirror Confinement Experiments Division; Dr. Evelio Sevillano, promoted to Assistant Group Leader for diagnostics in the Mirror Confinement Experiments Division; Joshua Stillerman, promoted to Systems Programmer/Analyst in the Mirror Confinement Experiments Division; and John Tarrh, promoted to Manager, Mirror Confinement Experiments Division.

The Plasma Fusion Center has also hosted several Visiting Scientists in the various research programs. They are: Dr. Gerhardt Berge (University of Bergen, Norway), MHD stability theory for stellarators and torsatrons; Dr. Boyd Blackwell (Plasma Research Laboratory, Australia), ICRF heating on Alcator C; Dr. Franklin Chang-Diaz (NASA), plasma propulsion; Dr. Charles Curtis (University of Arizona), edge-plasma effects; Dr. John Davies (Clark University), theory of free electron lasers; Dr. Henry Freund (Science Applications International Corporation), theory of free electron lasers; Dr. Hiroyuki Fujita (University of Tokyo), AC losses in ICCS conductors; Dr. Zengji Guo (Academia Sinica, PRC), tokamak fusion technology and engineering; Dr. Michael Hayes (Dartmouth College), Versator ECRH program; Dr. Shingi Hiroe (ORNL), TARA x-ray measurements and fluctuation studies; Dr. Hitusi Hojo (Hiroshima University), tandem mirror research; Dr. Elizabeth Källne (Joint European Torus), soft x-ray emission from Alcator C; Dr. Jan Källne (Joint European Torus), soft x-ray emission from Alcator C; Dr. Katsumi Kondo (University of Kyoto), plasma spectroscopy on Alcator C; Dr. Michael Mauel (Columbia University), TARA heating experiments; Dr. Lajos Pocs (Central Research Institute for Physics, Hungary & IREQ), particle reflux in TARA; Dr. Hirobumi Saito (Japanese Institute of Space and Astronautical Science), high-power gyrotrons; Dr. Frederick Seguin (American Science and Engineering), impurity transport and MHD phenomena in Alcator C; Dr. Abhijit Sen (Physical Research Laboratory, India), theory of free electron lasers; Dr. Yasushido Shindo (National Bureau of Standards), superconducting magnet design studies; Dr. Amarjit Singh (Central Electronics Engineering Research Institute, India), high-frequency gyrotron studies; Dr. Richard Slusher (Bell Laboratories), CO<sub>2</sub> laser scattering from lower hybrid waves in Alcator C; Dr. Clifford Surko (Bell Laboratories), CO<sub>2</sub> laser scattering from lower hybrid waves in Alcator C; Dr. Naftali Tishby (Chaim Weizmann Fellowship), theory of stochasticity; Dr. Trach Minh Tran (National Science Foundation, Switzerland), gyrotron and free electron laser theory; Dr. Han S. Uhm (Naval Surface Weapons Center), theory of beam-plasma systems with intense self fields; and Dr. Xin-yi Yao (Institute of Physics, Chinese Academy of Sciences), gyrotron heating experiments on TARA.

#### GRADUATE DEGREES

During the past year, the following students graduated with theses in plasma fusion and related areas: Wan Hoe Choe, Ph.D. in Nuclear Engineering; Anna Marie Dimos, Ph.D. in Physics; Eric Esarey, Ph.D. in Nuclear Engineering; Richard Garner, Ph.D. in Physics; Tae Kyung Gil, S.M. in Nuclear Engineering; Camilo Gomez, Ph.D. in Physics; Philip Goodrich, S.M. in Nuclear Engineering; Godehard Hilfer, Ph.D. in Nuclear Engineering; Brian LaBombard, Ph.D. in Nuclear Engineering; Rene LeClaire, Ph.D. in Nuclear Engineering; Boro Malinovic, S.M. in Nuclear Engineering; Herbert Manning, Ph.D. through Harvard University; Julio Martinell, Ph.D. in Physics; Matthew Mayberry, Ph.D. in Physics; Dean Miller, S.M. in Nuclear Engineering; Juan Moreno, Ph.D. in Physics; John Petillo, Ph.D. in Nuclear Engineering; Patrick Pribyl, Ph.D. in Electrical Engineering & Computer Science; Pasquale Rezza, S.M. in Mechanical Engineering; Rajeev Rohatgi, Ph.D. in Physics; Scott Texter, Ph.D. in Nuclear Engineering; and Alan Wan, Ph.D. in Nuclear Engineering.

We take this opportunity to wish these graduates success in their future professional endeavors.

RONALD C. DAVIDSON

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## Research Laboratory of Electronics

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### INTRODUCTION

The Research Laboratory of Electronics (RLE) is the Institute's oldest interdisciplinary research laboratory, founded in 1946 as the natural continuation of the wartime Radiation Laboratory. Initially, RLE was formed to bring together interests in physics and electrical engineering to work on problems in electromagnetic radiation, circuits, and specialized vacuum tubes. Over the years, however, RLE has branched out into a number of directions, and in fact, has been the root from which many other MIT laboratories have grown. Research within RLE is conducted by approximately 75 faculty members who are affiliated with the Departments of Electrical Engineering and Computer Science, Physics, Chemistry, Materials Science and Engineering, Aeronautics and Astronautics, Nuclear Engineering, and Linguistics. During the past year, there have been approximately 250 graduate students and 100 undergraduates working on research projects within RLE. Major support for this research is derived from the Joint Services Electronics Program (JSEP) of the Army, Navy, and Air Force; other Defense Department agencies; the Department of Energy (DOE); the National Science Foundation (NSF); the National Institutes of Health (NIH); and the National Aeronautics and Space Administration (NASA). This support is combined with substantial contributions from industry and private foundations. While RLE has a very heterogeneous character, its organization can be seen in two major thrusts, one focused on electronics and optics, and the other centered on language, speech, and hearing. In addition, there are seven smaller focus areas and some individual activities which have a small amount of coupling to other projects within RLE.

### ELECTRONICS AND OPTICS

In this area, research ranges from the production and characterization of electronic materials to processing techniques, device physics, high-performance integrated circuit design, and architectural considerations for specialized systems. RLE brings together experts in physical chemistry, condensed matter physics, electronic materials, device design and characterization, processing innovation, high-performance integrated circuit design techniques, and architectural strategies for special purpose applications which include digital signal processing and image processing.

Professor Sylvia T. Ceyer is continuing experiments on molecular beam surface scattering in order to study the detailed chemistry which occurs during the plasma etching of silicon and gallium arsenide. New experiments which probe the molecular chemisorption dynamics of carbon monoxide on nickel (111) have provided evidence to support the existence of a precursor molecule to chemisorption. During this period, Professor Keith Nelson continued his study of impulsive, coherent interactions between light and matter. These experiments have provided measurements of phase transition dynamics in several inorganic and organic crystals, and the measurement of electrooptic switching times and efficiencies in selected crystals.

In the Submicron Structures Laboratory, under the direction of Professor Henry I. Smith, further advances were made in understanding quantum transport in semiconductor devices with deep-submicron features. Quantum tunnelling in silicon inversion layers was observed over distances of approximately 100 nanometers. Such observations could eventually lead to a new generation of ultra-high density, quantum-coupled electronic systems. Grain growth stimulated by ion bombardment was achieved at low temperatures in semiconductor films, thus providing the basis for single-crystal films on amorphous substrates. Principal Research Scientist John Melngailis used a focused ion beam to assist in the deposition of metals such as gold, as well as direct maskless, resistless implantation. These techniques have led to integrated circuit microsurgery by redeposition, leading to increased yield in integrated circuit manufacturing. Professor Carl V. Thompson observed and successfully modelled the Fermi energy dependence of grain boundary mobility in semiconductors. Large aluminum grains (up to one-millimeter wide and one-micron thick) have been formed to make a single-crystal interconnect.

In the optics research area, Professor Clifton Fonstad successfully demonstrated a new laser array configuration which yielded fundamental mode operation. New analytical techniques for modelling optical waveguides have also been developed with a view toward very-high-speed communication in electronic and optic systems. During the past year, Professor Hermann Haus obtained the first fabrication of a fully integrated Mach Zehnder waveguide interferometer in gallium arsenide. These nonlinear waveguide interferometers have interesting properties in terms of the ideal limit of negligible loss, since they can serve as an ideal quantum measurement apparatus. A new picosecond and femtosecond laboratory

facility was structured by Professor James Fujimoto to study ultra-fast processes in electronic materials. In addition, time-resolved techniques to investigate laser tissue interaction, as well as diagnostics of biological systems, utilize these techniques. A new program to investigate ultra-high-speed carrier dynamics in gallium arsenide was initiated by Professor Erich Ippen. Carrier relaxation phenomena were studied on time scales measured as short as tens of femtoseconds, and are among the fastest such measurements performed to date. Also, nonequilibrium electronic phenomena in metals are being studied through the development of new femtosecond laser sources. Professor Peter Wolff is pursuing a wide variety of experiments in the area of infrared, nonlinear optics. Studies of free carriers in semiconductors show that optical nonlinearities are caused whenever the properties of electron states vary with energy, such as a metal-insulator transition. Recent results have provided the first example of a sizeable optical nonlinearity caused by the scattering of electron-impurity interactions in these materials.

In condensed matter physics, theoretical and experimental studies are coordinated to provide an insight into a variety of novel states of matter. Professor A. Nihat Berker, by using renormalization-group analysis, derived a new relation between critical exponents for specific heat and correlation length under random fields in the study of chemisorption. In this area, substrate imperfections differentiate locally between surface sublattices, thereby creating a random field situation for epitaxial ordering. These results are immediately applicable to current surface formation experiments. Professor John Joannopoulos provided the first ab-initio calculations on a polar semiconductor. He also provided predictions for the microscopic, geometric structure of various surface reconstructions and structural phase transitions on these surfaces. Professor Patrick Lee continued to provide theoretical interpretation for narrow (quasi-one-dimensional) inversion layers in MOSFETs, in order to understand the large resistance fluctuations in these structures. This work has been extended to include the presence of a magnetic field. These are not time fluctuations, but rather, fluctuations from one disordered sample to another; from one magnetic field to another; or from one value of Fermi energy to another. It is conceivable that these fluctuations might explain universal  $1/f$  noise. Experimental studies of narrow MOSFETs at low temperatures were made by Professor Marc Kastner, leading to the study of new quantum mechanical effects in electronic transport. The coordination of ultra-small device fabrication, experimental studies, and theoretical interpretation within RLE have provided much excitement in the condensed matter physics area. In culmination of a major construction effort, the MIT/IBM beam lines at the national synchrotron light source have now been fully commissioned. One line provides the most intense monochromatic laboratory x-ray beam in the world, and is now being used to study the hexatic phase in liquid crystal material by Professors Robert Birgeneau and J. David Litster. Hexatic states are intermediate between normal liquids and solids. They have short-range positional order similar to a liquid or glass, but long-range orientational order similar to a crystalline solid. Extensive studies to develop crystalline axes and positional order have shown that the transition is both continuous and reversible. Thus, one can study the order evolution on either freezing or wetting. These experimental results are also supported by a highly successful theory for three-dimensional hexatic phase growth.

In the VLSI circuit design area, Professor John Wyatt derived a proof of an improved timing bound algorithm. This method has been adopted to bipolar ECL circuits, and the results have been extended to a large class of "diffusion-type" dynamical systems. Professor Lance Glasser completed a novel reliability simulator that provides guidance for highly robust designs. He also demonstrated a high-performance LSI chip for multiprocessor input/output that provides accurate synchronization between many processors in a highly distributed computational architecture. Professor Jonathan Allen extended techniques for regular structure generation which include compaction capability and performance estimation, so that large systems can be readily reconfigured with new technologies, and the resulting performance accurately estimated. New studies also seek to provide a rigorous basis for the multiple constraint domains utilized in VLSI design. Thus, a formal design space specification is available for design exploration algorithms.

#### LANGUAGE, SPEECH, AND HEARING

RLE has a large, coordinated effort in speech, hearing, and the phonological aspect of language. This effort unites contributions ranging from auditory physiology to auditory psychophysics, speech communication, and linguistics. Professor Kenneth Stevens continues to obtain experimental evidence that will elucidate the process by which speakers encode an utterance's discrete linguistic representation into continuous movements of the speech production system, and into sound patterns. In turn, listeners decode these sound patterns into a corresponding, discrete representation. These fundamental studies have been utilized by Dr. Dennis Klatt to provide insight into improved speech synthesis models, including an appropriate speech synthesis framework for different languages. Dr. Joseph Perkell is launching a major set of experiments to understand the control and coordination of speech articulatory movements, having just completed the construction of a complex movement transducer system. By using external coils, magnetic fields are established within the subject's head. Minute sensors are then attached to the various articulators to characterize the motions under study. This new



procedure avoids the difficulties of earlier x-ray-based techniques for motion study. Professor Victor Zue completed the design of an auditory-based front-end for speech recognition that is useful for acoustic segmentation and broad phonetic classification. Algorithms for recognizing nasal consonants and syllabic nuclei have also been developed. The design and analysis of a database for phonetically compact sentences has also been achieved.

Perceptual research on hearing and touch is being conducted by Professor Louis Braid, Senior Research Scientist Nathaniel Durlach, and Principal Research Scientist Steven Colburn. The binaural hearing capability of impaired listeners has been studied on several binaural tasks. The ability of listeners with both normal and impaired hearing to discriminate broadband, continuous spectra on the basis of spectral shape has also been investigated with a view toward improved aids for hearing. These studies were based on both a fundamental understanding of normal and impaired hearing, as well as the limitations of currently available aids. Effects of noise on intelligibility, amplitude compression, frequency lowering, and clear speech have been studied in order to provide guidance for the design of these hearing aids.

In cooperation with the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary, long-range studies on the hearing mechanism are being pursued. The main emphasis is to understand auditory physiology by describing signals and mechanisms throughout the pathway, from the external auditory meatus to the auditory cortex. Professor Nelson Kiang is conducting studies aimed at understanding how single neurons contribute to the gross electrical activity recorded from the head's surface. This can lead to improved diagnosis of otologic and neurologic disorders. Professor William Peake is studying the middle ear of three mammalian species in order to understand how acoustic power couples to the cochlea. Measurements in cats' ears have indicated that while the middle ear transduction process provides impedance "matching" for frequencies above two kilohertz, there is a gross mismatch below that frequency, indicating that new models for mechanical coupling must be provided. Professor Thomas Weiss has studied cochlear mechanisms by which sound stimuli are encoded from fluid motion into auditory nerve signals. Micromechanical properties of sensory hair cell bundles have been studied, leading to new theoretical models for this important mechanical behavior. Professor Lawrence Frishkopf has also been concerned with hair cell transduction mechanisms, and has measured the motion of hair cell stereocilliary tufts in relation to the underlying basilar membrane in the alligator lizard's cochlea. In the cochlea's basal region, a micromechanical basis for frequency analysis has been established. By stimulating the efferent nerves to the cochlea, Dr. John Guinan has produced mechanical changes in the cochlea which can be monitored as changes in sound pressure in the ear canal. This provides a new method to monitor human efferent activity, and indicates the role of efferent activity in human hearing. Experiments with intracochlear electrodes are being conducted by Dr. Donald Eddington, in an attempt to understand hearing achieved through electrical stimulation of the cochlea or auditory nerve. Encouraging results have been obtained with these devices. It is anticipated that the fundamental differences between currently implanted subjects will provide a general insight into the coding and recognition of speech and other acoustic signals.

## FOCUS AREAS

### Atomic and Molecular Physics

Professor Shaoul Ezekiel studied several properties of passive resonator gyroscopes, including lock-in behavior and the use of multi-turn fiber interferometers. Additional studies focused on wavelength stabilization in a variety of light sources that are important in applications such as communication, wavelength multiplexing, sensors, and spectroscopy. Professor David Pritchard measured the scattering of atomic deBroglie waves from a standing light grating, thus confirming the longstanding prediction of Kapitza and Dirac that momentum is transferred by pairs of absorbed and stimulated photons. In addition, a new experiment has begun to determine trapped ion masses with unprecedented accuracy. In this experiment, trapped ions have been detected by using a superconducting coupling coil and quantum interference detector, providing a new methodology for extremely accurate mass measurements.

### Plasma Physics

Professor George Bekefi is continuing his study of efficiency enhancements for free electron lasers by utilizing various innovative wiggler configurations. He also collaborated with Professor Miklos Porkolab on several experiments using the Versator, a medium-sized research tokamak reactor, in order to study the basic physics of plasma heating and current drive with radio frequency waves. In the area of theoretical plasma physics studies, Professor Abraham Bers modelled and analyzed problems which involve coupling, propagation, energy and momentum deposition, and induced transport in the interaction of electromagnetic fields with plasmas. Radio frequency current drive studies have indicated its possible



use to stabilize certain magnetohydrodynamic instabilities driven by ohmic currents, leading to a new application of current drive. During the last year, a new experimental concept called Ignitor was developed by Professor Bruno Coppi and his collaborators. This is a compact, high-magnetic field experiment that incorporates new technological solutions to prove if a plasma composed of heavy hydrogen isotopes can reach fusion ignition conditions. Furthermore, by using the profile consistency principle, Professor Coppi successfully predicted that temperature profiles will remain insensitive to changes in the plasma heating source, a result contrary to classical transport theories.

#### Radio Astronomy

Professors Bernard Burke and John Dreher are studying the distribution of matter in galaxies, and in the universe as a whole. The primary methods being utilized are the study of radio and light wave deflection by the gravitational fields associated with large-scale aggregations of matter, and by direct observations of the gravitational interactions of galactic systems. Ongoing experiments utilize the very-large-array and the very-long-baseline interferometry techniques to probe these effects, leading to a large data analysis program and corresponding image analysis. Professor David Staelin constructed a new passive microwave 118-gigahertz spectrometer. When flown in high-altitude aircraft, this spectrometer provides preliminary maps of the three-dimensional atmospheric temperature field. These fields have revealed the existence of extensive tropospheric thermal waves.

#### Image Processing

The Advanced Television Research Program (ATRP), led by Professor William Schreiber, seeks to develop the science and technology which is basic to improved television systems. Major investigations were completed in motion-compensated interpolation, enhancement, and the restoration of moving image signals. Psychophysical studies related to moving image perception were performed by Professor Staelin. These studies show that the human visual system is relatively insensitive to rapid changes in certain chrominance signals, and imply that future television systems could be operated at reduced bandwidth without perceptual degradation. An extensive, high-definition television simulation facility was constructed, and a new audience research facility situated in a local shopping mall has provided many new insights into image preference. Professor Donald Troxel introduced hierarchical object modelling and ray tracing techniques which substantially minimize the computation time for conventional ray tracing algorithms. These new procedures are being utilized as part of a design for high-performance, interactive graphics workstations.

#### Digital Signal Processing

Professor Alan Oppenheim is developing new algorithms closely related to implementation issues for several applications. As these algorithms grow more complex, a combination of both numerical and symbolic processing is being used. This will lead to a new class of techniques designated as knowledge-based signal processing. Professor Jae Lim developed a new high-quality, medium-rate speech coding system, as well as a system for image restoration and interpolation by motion compensation. The relationship of high-performance algorithms for spectral estimation and pole-zero modelling to appropriate architectures is being studied by Professor Bruce Musicus. This has led to the introduction of an inexpensive, high-performance design for a cellular architecture suited to these applications.

#### Electromagnetics

Professor Jin-Au Kong and his research group are pursuing a wide variety of studies in electromagnetic wave theory and application. Electromagnetic wave propagation in the complex interconnect structures of integrated circuit systems has been studied by using a transient response technique based on the method of characteristics and perturbational series under given circuit parameters. Additional techniques have been developed, and have led to realistic, theoretical models for the remote sensing of many different environments. Dr. Min-Chang Lee has concentrated on the electromagnetic wave probing of the ionosphere and magnetosphere, including ionospheric effects on satellite communications, and nonlinear electromagnetic wave interactions with space plasmas. These techniques are aimed at remote sensing of space plasma electrodynamics, and the means to modify the ionosphere with high-power electromagnetic waves.

## Communications

Professor Jeffrey Shapiro has developed theoretical and experimental insights into the generation, detection, and application of squeezed state light beams. During the past year, new experimental techniques have led to successful squeezed state generation. Future high-sensitivity optical precision measurements and integrated optics devices may rely on quantum noise manipulation achieved through these squeezed states for improved sensitivity and new network functionality. Dr. Robert Rediker has been working on the feasibility of producing lasers based on semiconductors, with an average power in kilowatts. By using an ensemble of five mutually coherent semiconductor diode lasers in an external cavity, successful operation of this system has been demonstrated. This can be used in communication systems with very narrow band receivers.

In addition to the focus areas described above, several other research directions have been pursued within RLE. Professor Sow-Hsin Chen has been studying the structure and dynamics of colloidal solutions by using small angle neutron scattering and photon correlation spectroscopy. These techniques have been used to study the Brownian dynamics of strongly interacting colloidal systems. Professors Campbell Searle and Jerome Lettvin conducted a variety of physiological experiments aimed at the accurate modelling of peripheral vision and cell membrane action. In particular, two new VLSI chips are being designed that will allow experimentation with neural networks that are more isomorphic to real nervous systems. Professor John King is using molecular microscopy techniques to study biological and material surfaces in order to understand mechanisms of embrittlement, integrated circuit failure, and selectivity on a molecular biology scale. A new method of surface analysis by probe contact and subsequent field desorption, ionization, and mass spectrometric analysis has been developed to facilitate the positive identification of atoms in complex samples.

JONATHAN ALLEN

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## Sea Grant College Program

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When Congress established Sea Grant in the mid sixties, it saw the nation's universities as a source of information and research results which would be useful in developing and managing marine and coastal resources. MIT received the first award from this new national program in 1969 when the Department of Ocean Engineering received a grant to develop a series of innovative textbooks. The affiliation was strengthened a year later when a larger grant was awarded to start up a full research and education program. By 1976, so much had been accomplished by the faculty, students and staff, that MIT became the first private university to be designated a Sea Grant College Program, a designation that allowed the Institute to compete for the Program's highest level of funding. Awards are shared by 30 university-based programs through the National Office of Sea Grant in the National Oceanic and Atmospheric Administration in a competing proposal process. In winning a grant each program is required to match the National Office's support by at least one third from other sources, including industry, universities, state and local governments, or private foundations. Congress in establishing this requirement felt that the programs would be more flexible and responsive if the people who were going to make use of the Sea Grant-generated knowledge and technology were full, committed participants in the research and education process.

Last year the National Sea Grant Program provided the Institute with \$1.7 million in support; this was matched by \$1.3 million from industry, the Commonwealth, and MIT. Sea Grant also received \$250,000 in related research support from a number of federal agencies. These funds supported 25 faculty and 28 students from eight departments.

### RESEARCH

MIT began its affiliation with the National Sea Grant College Program in 1968. The Institute's own intellectual resources and in the needs of the marine community are the two driving forces which mold the Program's focus. At present there are five areas which envelop and concentrate our attention: coastal processes and environmental modelling; offshore engineering; technology development and management for ocean uses, including the Sea Grant Marine Research Center; undersea work vehicles and teleoperation; and living resource utilization. Most recently, MIT's expertise in the new field of biotechnology is being called upon for application to marine problems and opportunities.

The goal of coastal process research is to conduct interdisciplinary hydrodynamic studies, linking laboratory and field measurements in an ongoing attempt to model and forecast variability in the nearshore environment. Last year research addressed the efficient computation of surface water movement and associated dispersion of dissolved substances; the transport of suspended particles; subsurface movement in coastal marshes; storm surges and related sediment transport, and the fate of volatile pollutants. The results of this research are being incorporated into a flexible and modular simulation model that will be an important tool in pollution abatement, particularly in Boston Harbor and Massachusetts Bay.

Both the civil and ocean engineering departments have made major contributions to Sea Grant sponsored offshore facility research. The faculty and students from these two departments have aimed to develop technical data and analytical methods for designing offshore structures and their subsystems, particularly those that will operate in ice-infested areas and deep waters. During this past year, support continued for the development of a reliable and rational method to estimate in-situ engineering properties of marine sediments, both for compliant and fixed offshore facilities. The strength deformation properties of arctic silts were also studied. A conceptual model was begun to describe mathematically how ice itself deforms. Four research projects focused on understanding hydrodynamic forces and the loads they impose on structures. Finally, in this research area interest continued in trying to quantify the dynamics of the risers and cables which will be used to anchor deepwater structures.

Sea Grant's Marine Research Center, a focus of technology development for ocean use and management, is a mechanism which allows MIT and industry to work closely on problems of critical concern in marine resource development. Last year the Center focused on problems faced by the offshore industry. Working with an advisory committee of 20 companies, the Center identified five research projects which offshore designers could put to work to engineer platforms that would be safer and more economical to build and operate. In addition to time spent meeting with MIT faculty and students and in reviewing projects, the companies provided research funds of \$195,000 to facilitate the transfer of technologies from MIT's laboratories to their own.

Industry collaboration was also a principal highlight of the unmanned, underwater work vehicle research area in the past year. A leading manufacturer of undersea vehicles sent one of his most promising young engineers to MIT for six months to supervise a team of MIT undergraduates charged with outfitting MIT's undersea robot, SEAGRANT I. The vehicle, which was given to the Institute by another vehicle company, is needed to test control techniques and strategies for active and/or passive grabbers and tethers in conjunction with vehicle thrusters and manipulators. In a complementary effort, Sea Grant sought out other federal funds for undersea robotics research. In the spring of 1986 the Program prepared an interdisciplinary, interinstitutional proposal to unite artificial intelligence and engineering in the design of an underwater vehicle which could travel over long distances and then operate in a confined area, such as a coastal harbor. The research group includes a research scientist from the Ocean Engineering Department at the Woods Hole Oceanographic Institution and assistant professors from MIT's Department of Mechanical Engineering, Earth, Atmospheric and Planetary Sciences, and the Artificial Intelligence Laboratory. The team will spend a year formulating a full proposal and work plan that could garner annual research support of \$1 million for three or four years.

In the area of living resource utilization, Sea Grant seeks to advance technologies which will make more efficient use of ocean and coastal biosystems. In the past, the Program has concentrated on developing fishing gear and food processing technologies, but those efforts have been broadened in the last three years to take advantage of advances in genetic engineering and biotechnology. Current work focuses on fisheries as a potential source of valuable biomedicinals. One project this past year showed shark cartilage may be much more powerful in stopping new blood vessel growth around tumors than the conventionally used source, calf cartilage. Another study was initiated to develop a methodology for using marine biopolymers, including alginates, carrageenan, and chitosan, in the controlled release of drugs and food preservatives. The omega 3 fatty acids in oily fish have proved effective in reducing the risk of coronary heart diseases. Sea Grant research undertaken this past year is assembling information on the availability, properties and composition of fatty acids from locally available fish.

#### ADVISORY SERVICES

There are three parts to MIT's advisory service— the Marine Industry Collegium, the Marine Advisory and Fisheries Engineering Service (MAFE), and the Communications/Information Service. The Collegium, modeled on the Industrial Liaison Program, is a fee-for-membership organization which fosters industry-Institute cooperation. Collegium members have an opportunity to attend several workshops each year, meeting with faculty and students to discuss and review research in progress. Last year three workshops were held at MIT and a final meeting took place at the Woods Hole Oceanographic Institution. The topics discussed were design considerations for the use of ropes and cables in the marine environment, recent advances and applications of biotechnology to the marine field, capacity of offshore friction piles in clay, and oceanographic instrumentation.

The Sea Grant Marine Advisory and Fisheries Engineering Service interfaces with state and local organizations, focusing principally on fisheries and coastal issues. MAFE utilizes the Naval Ship Research Development Center in Bethesda, Maryland to conduct advanced fishing gear research in the David Taylor Model Basin. Last year the facilities were made more accurate and efficient for fisheries research with the development of a computer-based data acquisition system. Two students from the Department of Ocean Engineering aided MAFE; one undertook a study on the feasibility and efficiency of retrofitting fishing vessels with bulbous bows and the other developed a study of how engine and propellor characteristics affect the towing power of fishing boats. The New England Regional Fishery Management Council, which is responsible for developing management plans for the major fish species caught in the Northeast, turned to MAFE's maritime anthropologist to analyze the cultural impacts on traditional fishing communities of the Council's Groundfish Management Plan. For the third year MAFE coordinated COASTWEEK, a state-wide effort that involved 60 organizations, to increase the public's appreciation and management of coastal zone resources.

The Communications/Information Service added 36 reports to a publication series which was initiated in 1970. All of these reports are housed in the Marine Information Center, a small reference facility which also includes a complete set of WHOI reports and publications from the entire Sea Grant network. Last year, the Information Specialist developed an innovative PC-based catalog system which has facilitated easier and more complete response to information requests from the Institute's community, marine businesses and the general public. Communications/Information produces MIT Sea Grant's newsletter, the MIT Sea Grant Quarterly Report and an information directory, Marine-Related Research at MIT.

## EDUCATION

The educational goals of Sea Grant are to provide educational opportunities to university students, professionals in the marine field, and the public. Support for graduate students is included in almost all research projects. In addition the Program continues to increase the number of grants awarded through UROP. Last year six were given for the fall semester and six in the spring to undergraduates in the departments of Ocean Engineering, Earth, Atmospheric and Plantetary Sciences, Mechanical Engineering, Civil Engineering, and Aeronautics and Astronautics.

Last year the 14th Annual Sea Grant Lecture and the Fourth Annual Sea Grant Seminar Series were held in April on the subject of Ocean Disposal of Public Wastes: Technology and Policy for the Future. The Program concentrated on identifying research initiatives that would aid in the management of ocean waste disposal. In the spring of 1986, plans were started for the next Lecture Seminar Series to be held in the fall on Undersea Teleoperators and Intelligent Autonomous Work Vehicles.

Sea Grant continued its joint program with the Commonwealth and the Massachusetts Maritime Academy to make available continuing education opportunities to New England fishermen.

## PROGRAM MANAGEMENT

The Program Director is Professor Chryssostomos Chryssostomidis, Professor in the Department of Ocean Engineering; Associate Research Directors are Marcus Karel, Professor in the Department of Applied Biological Sciences, and Keith D. Stolzenbach, Associate Professor in the Department of Civil Engineering. E.R. Pariser, Associate Director for Education and Training and a principal architect of the MIT Sea Grant Program, will retire on July 1, 1986. Norman Doelling continues as Executive Officer and Manager of the Marine Industry Advisory Service Collegium. Arthur B. Clifton manages the Marine Advisory and Fisheries Engineering Service, Elizabeth T. Harding is the Manager of the Communications Information Service, and Lawrence W. McKinnon is the Program's Administrative Officer.

Sea Grant administers the Doherty Professorship endowed by the Henry L. and Grace Doherty Foundation for young faculty at the Institute. In the spring of 1986, Renee Fitts, Assistant Professor in the Department of Applied Biological Sciences, and Dale Karr, Assistant Professor in the Department of Ocean Engineering, were named as new recipients of the chair. At the same time it was announced that Triantaphyllos R. Akylas, Assistant Professor in the Department of Mechanical Engineering, would continue to hold the chair for a second year.

## CHRYSSOSTOMOS CHRYSSOSTOMIDIS

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## Technology and Development Program

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The Technology and Development Program's (TDP) primary objective is to provide a focus at MIT for research and education related to the role of science and technology in the socioeconomic growth of developing countries. Its more specific objectives are to: (1) promote an awareness of the relationship between science, technology, and development on the part of faculty and students at MIT; (2) provide a focal point for the activities of faculty, students, and visiting scholars interested in the field of technology and development; and (3) serve as a contact for interested organizations outside MIT (government, academic, private sector) to access the Institute's resources and its knowledge of developing countries--particularly of their socioeconomic and technological problems. The TDP carries out its objectives through research, academic programs, and contacts with international and national organizations that are concerned with, or have an interest in, broad areas of technology and development.

The Program Director is Professor Fred Moavenzadeh, William E. Leonhard Professor of Engineering in the Department of Civil Engineering. Professor Nazli Choucri of the Department of Political Science is the Program's Associate Director and Chairman of the Policy Committee. Committee Members are Professors Moavenzadeh, Daniel M. Holland of the Sloan School of Management, and Jack P. Ruina of the Department of Electrical Engineering.

### Highlights of the Past Year

The TDP's highest priority during the past year has been diversification. In support of this general objective, the TDP has undertaken several specific initiatives in order to:

- Establish new institutional ties and strengthen existing ones with foreign, U.S., and international organizations with similar concerns.
- Seek new sources of financial support for research and educational activities at MIT which will further TDP's objectives.
- Expand the scope of TDP involvement at MIT, especially in terms of its academic contribution.

The following sections of this report summarize the specific activities undertaken in 1985/86.

### Roundtable on Science, Technology, and Development in Latin America

From October 22 to 24, 1985, the TDP held its second International Roundtable on Science, Technology, and Development. This year the regional focus was on Latin America, and fifteen distinguished experts attended the Roundtable, representing ten different countries and a variety of development-oriented institutions from the public, private, and academic sectors. Funding for the Roundtable was provided by the Tinker Foundation, with the Inter-American Development Bank and Organization of American States providing high level staff support.

As with the previous roundtable focusing on the Arab World, the objective for the TDP was to discuss the most critical issues facing high level government, industry, and university officials in this region, and consider how MIT in general and the TDP in particular can provide timely and relevant assistance. The discussions of the Roundtable focused on the following general topics:

1. The importance of science and technology for development in Latin America, and its current status throughout the region.
2. The impact of the current financial crisis facing several countries of the region.
3. Adequacy of the existing science and technology infrastructure and policy instruments in the individual countries, and in the region as a whole.
4. The need for increased regional cooperation in science and technology, and for more interaction with appropriate U.S. institutions.

The Proceedings of the Roundtable are scheduled for publication during the summer of 1986.

### Other Specific Initiatives

A major collaborative program involving TDP, Kuwait University, and the Kuwait Institute for Scientific Research was proposed during 1985/86. This program would be similar in scope to the Cairo University/MIT

Technological Planning Program that the TDP has conducted since 1977. The proposal was reviewed by MIT's Committee on International Institutional Commitments, and the TDP is now awaiting approval of the Kuwait Foundation for the Advancement of Science and Technology to proceed with more specific negotiations.

The Kuwait Investment Authority also contacted the TDP and requested a proposal for a comprehensive macro-analysis and sectoral review of the Kuwaiti economy. Further discussions will take place on this proposed research during the summer of 1986.

On a visit to South Korea, the TDP Director entered into preliminary discussions for a collaborative program with the Korean Institute of Technology (KIT). This university was recently established by the Government of Korea to provide the necessary scientific and technological manpower for future growth of Korean industry into advanced technological areas such as materials science, electronics, and biotechnology. The President of KIT is expected to visit MIT in the near future for additional discussions.

Contact was also maintained with the Indonesian Institute of Technology (ITI), to discuss ways in which the TDP could assist in the development of this institution, and promote its contribution to the scientific and technological development of Indonesia.

A research project was jointly supervised by Professor Choucri (TDP Associate Director) and Professor Myron Weiner of the Center for International Studies on "The Internationalization of Policies Affecting International Migration". Sponsored by the Ford Foundation, this project has explored the conditions under which unilateral, bilateral, regional, or other multilateral actions are pursued and with what consequences both for international migration and for relations among states. A specific case study will focus on migration in the Middle East.

In the academic area, an interdepartmental faculty committee under the leadership of Professor Choucri has established a new graduate program on the Middle East, focusing on technology, development, and public policy. The program has been approved by the appropriate faculty committees, and will commence in the fall of 1986. Two core courses have been developed at the graduate level for this program, "Politics, Technology, and Development in the Middle East", and "Technology, Business, and Public Policy in the Middle East". Instruction will be jointly undertaken by faculty from the Department of Political Science, the History Faculty, the Department of Urban Studies and Planning, the Sloan School of Management, the Department of Civil Engineering, the Science, Technology and Society Program, and the Aga Khan Program in Islamic Architecture.

#### Cairo University/MIT Technological Planning Program

Since 1977, the TDP has participated in a major program in Egypt to assist Cairo University in the establishment of a Development Research and Technological Planning Center. Modeled on similar centers at MIT, this organization now provides an institutional mechanism at Cairo University for conducting contract research on development topics with Egyptian and international organizations.

In the fall of 1985, the U.S. Agency for International Development conducted its third major evaluation of the CU/MIT Program. The evaluators found that in the Cairo University/MIT collaboration, significant achievements have been made in solving specific development research problems, fostering new areas of expertise, and strengthening institutional capabilities at Cairo University and other Egyptian organizations. The CU/MIT Program has successfully demonstrated the potential of universities and inter-university collaboration in the development of a national science and technology infrastructure. It has also shown how universities can interact with government and industry to achieve common goals and develop more constructive partnerships. The evaluation team's report made special mention of the strong MIT faculty commitment to this effort, and the high quality of the research results.

As a result of the evaluation, the TDP is currently engaged in negotiations to extend the CU/MIT Program to 1988. Should these negotiations proceed as expected, an additional \$2.6 million will be available to support the program's activities at MIT over the next two academic years.

In 1985/86, MIT participation in the CU/MIT Program included 12 faculty members, four research associates, and eight graduate research assistants from seven academic departments. The specific activities funded by the program over the past year included the following research projects:

Energetics in the Metal Industries: Comprehensive analyses of material and energy consumption for each of the various processes in the production of crude steel in Egypt. Technical and economic feasibility analysis of recommended solutions to enhance productivity, product quality, and energy conservation. MIT Principal Investigator: Professor David Gordon Wilson, Department of Mechanical Engineering.

Energy-Economy Interaction and Energy Policy: Development of analytical models to provide a comprehensive view of policy issues and performance in the energy sector of Egypt. Included are the Egyptian Petroleum Model, the Egyptian Natural Gas Model, and the Short-Run Energy Macroeconomic Model, to explore, identify, and understand the uses of energy within the different sectors of the economy. MIT Principal Investigator: Professor Nazli Choucri, Department of Political Science.

Engineering Applications for the Plastics Industry: Development of a technological base for use of composite materials by the plastics industry in Egypt, and development of improved materials and processing methods for enhanced durability in new applications such as PVC pipes. MIT Principal Investigator: Professor Frederick McGarry, Department of Materials Science and Engineering.

Freight Service Planning and Marketing: Analysis of proposed organizational improvements in the Egyptian Railroads Organization, with respect to equipment and facility utilization, and overall coordination among the various operating units. Development of upgraded management information systems to be used by management and other operating staff. MIT Principal Investigators: Professor Joseph Sussman and Dr. Carl Martland, Department of Civil Engineering.

Hydrology of Agriculture: Simulation of water flow under different irrigation systems and under different types of soil stratification in Egypt. Models are to be verified and applied to determine optimal irrigation scheduling for plant growth, preservation of nutrients, and control of salt accumulation. MIT Principal Investigators: Professors Rafael Bras and Peter Eagleson, Department of Civil Engineering.

Intercity Multimodal Transportation Model: Development of an analytical framework to forecast the overall performance of the transport sector in Egypt, in terms of operating efficiency, revenues, costs, and user benefits. In addition, the establishment of technical, operational, and financial evaluation measures for each of the separate transport modes (railways, highways, waterways). MIT Principal Investigator: Professor Fred Moavenzadeh, Department of Civil Engineering.

Solar Pond Technology: Evaluation of the feasibility of solar pond technology in Egypt, through the construction of two demonstration ponds. Physical, chemical, and geological data are being monitored to evaluate pond performance and recommend future design techniques for larger ponds with electrical power generation capabilities. MIT Principal Investigator: Professor Donald Harleman, Department of Civil Engineering.

Water Resources Planning: The investigation and evaluation of various techniques for planning and managing Egypt's water resources. Project efforts, which originally focused on the High Aswan Dam, have been expanded in recent years to include more extensive areas of the Nile Valley, the Upper Nile, and the Delta. MIT Principal Investigator: Professor David Marks, Department of Civil Engineering.

In accordance with the current priorities of the Government of Egypt, it has been decided that future projects will focus largely on the area of productivity in Egyptian public and private sector organizations. One new project has been approved for the forthcoming year on "Improved Performance in the Prefabricated Housing Industry". Under the direction of Professors Eric Dluhosch and Wacław Zalewski in the Department of Architecture, this project will conduct a review and analysis of the prefabricated housing industry in Egypt, to identify technical, organizational, and resource bottlenecks, and propose corrective measures to enhance productivity.

Professor Elias Gyftopoulos of the Department of Nuclear Engineering visited Cairo to explore another project in the area of industrial productivity. In addition, a new project is being planned on VLSI systems, and discussions are underway with Professor Jonathan Allen of the Department of Electrical Engineering to determine the scope of MIT's participation.

Professor Kenneth Smith, Associate Provost and Vice President for Research at MIT, traveled to Cairo and participated in the program's seventh Annual Technical Conference in January 1986. In March 1986 Professors Moavenzadeh, Choucri, and Gyftopoulos participated in a seminar at the DRTPC on "Energy Policies in Egypt".

#### Other TDP Activities at MIT

During the spring semester of 1986, a seminar series was jointly sponsored by the TDP and Harvard's Center for International Affairs on "The Political Economy of the Middle East". A seminar series at MIT was also inaugurated by the TDP and the Department of Political Science on "Development and Change in the Middle East". Both will be continued in the fall semester of 1986.

Professor Alberto Marcati of the University of Calabria in Italy spent an academic year with the TDP as a visiting scholar. His research focused on development of a utility analysis model to evaluate competing bids in turn-key industrial projects in developing countries.

The TDP continued publication of its newsletter, "Technology and Development". Seven technical reports were published in the TDP Report series. A complete list of available publications can be obtained from the TDP office, E40-247.

FRED MOAVENZADEH



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## Technology Licensing Office

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During Fiscal Year 1986, several major changes occurred in the MIT Technology Licensing Office (TLO). The former director of the program, Arthur Smith, left MIT to go into private law practice. Niels Reimers, the director of Stanford's Office of Technology Licensing, agreed to spend a sabbatical at MIT as acting director of the TLO. Professor John Deutch set up an ad-hoc faculty committee to work with Niels Reimers to review MIT patent policy. This committee was chaired by Professor Kent Bowen. A final report of this committee was issued in May of 1986. The primary recommendation of the report was that the TLO shift its emphasis from the process of patenting and protecting MIT's intellectual property to the transfer of the technology. Thus, the focus of the TLO changed from the legal aspects of patenting and copyrighting to the business aspects of transferring technology to companies. The ad-hoc committee further recommended that TLO use outside counsel to handle the patent filing, and concentrate internally on the marketing and effective transfer of technology. The name change from the Patent, Copyright and Licensing Office to the Technology Licensing Office reflects the shift in emphasis.

Also during the year, John Preston was hired to become the new director of the Technology Licensing Office, and Lita Nelsen was hired as Technology Licensing Officer. Both bring extensive marketing, technology, and business expertise to the Office.

Lincoln Laboratory technology licensing policies have been evaluated with Dr. Walter Morrow and Mr. John McCook. This resulted in a slight policy change at Lincoln Laboratory allowing staff members to consult for the specific purpose of facilitating the transfer of their inventions to industry.

Total revenues from the TLO equaled \$2,751,222. This represents approximately a million dollar increase over the previous year; however, the TLO had an extraordinary income of \$1 million during the year from a patent infringement suit. During Fiscal Year 1986, there were 150 new inventions disclosed to the TLO. Ninety-five patent applications were filed, and 43 issued to MIT.

While it is somewhat early to assess the results of the new direction of the Office, the TLO has experienced an increase in the number of license agreements executed during the last two or three months. The new policies should enable a significant improvement in MIT's effectiveness at transferring technology to industry during the coming year.

JOHN T. PRESTON

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## Whitaker College of Health Sciences, Technology, and Management

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Interdisciplinary collaboration among faculty from the various MIT schools continues to provide a focus for our research and educational programs in the medical/biological field. Our staff also includes academic and research personnel, graduate and undergraduate researchers, as well as national and international visitors. This year, I am pleased to report on the following events and highlights in our programs.

### Program in Brain and Cognitive Sciences

This spring the faculty and the resources of the Psychology Department merged with those in computational neuroscience and molecular neurobiology in the Whitaker College to form a new Department of Brain and Cognitive Sciences. I will serve as Chairman of the new department in addition to my responsibilities as Director of the College. The purpose of this major reorganization is to integrate MIT's widespread efforts on understanding brain function, to provide a unified entity to focus Institute and outside support in this area, to encourage collaborations across disciplines, and particularly to provide the opportunity for comprehensive and multidisciplinary training of young scientists. MIT, with its deep strengths in molecular biology and artificial intelligence, as well as in more traditional areas of neurobiology and psychobiology, is in a unique position to train a new generation of scholars with knowledge of brain function. The goal is to create young scientists who will have a working knowledge of several of the most advanced approaches to understanding neural systems.

Multidisciplinary training of this type has been taking place spontaneously at MIT in the recent past, with excellent results. For instance, students in motor control and vision have been receiving training not only in neurophysiology and neuroanatomy but also in the computational approaches. In motor control, the emphasis has been on mechanics, computer simulation, motor psychophysics and motor neurophysiology. This type of combined training is feasible at MIT because of the existing close collaboration between researchers in motor neurophysiology with researchers in the Departments of Mechanical Engineering and Electrical Engineering and Computer Science (robotics). In the area of vision, students have been trained in the physiology and psychophysics of the visual system as well as in computational approaches. These interdisciplinary efforts to understand vision have enabled our faculty and students to make theoretically informed analyses of cell properties in visual areas. Another example of interdisciplinary training involves the area of development and neuroscience. Students of Professors Graybiel, Schneider, and McKay have been exposed to molecular techniques such as monoclonal antibody production, which refine our picture of cell types as well as our understanding of cellular interactions during development. In addition, theoretically inclined students of neuroanatomy have had the opportunity to become familiar with computational principles which make functional sense of the systems they study.

While MIT has been training students across interdisciplinary lines all along, the formation of the new Department of Brain and Cognitive Sciences will provide an additional impetus to these efforts. Specifically, our recruiting efforts in the area of neurobiology added two faculty in development and learning in 1984, Professors William Quinn and Ronald McKay. These appointments not only represent an important contribution to our training of students in the fundamental biology of neurons, but they also allow us to establish a bridge with the Department of Biology. Two additional appointments in this area are foreseen in the very near future.

We have also expanded in the area of computational neuroscience, with a new junior appointment, Professor Ellen Hildreth. By providing space in the Whitaker College building for Professors Poggio and Hildreth and their associates, we will promote close interaction between computation and the physiology of vision and motor control. Two new faculty appointments in the areas of physiology and computation are in process.

Because of the retirement of Professor Walle Nauta at the end of this academic year, we have been able to make an outstanding junior faculty appointment in neuroscience. We are pleased that Professor Mriganka Sur will join the new Department in July, 1986.

In addition, the department will be enriched by the transfer from Applied Biological Sciences of Professor Richard Wurtman, who will become a full member of the Department of Brain and Cognitive Sciences effective July 1, 1986. Dr. Wurtman adds expertise in the area of neuroendocrine regulation.

To support our endeavors, the College has received funds from the Pew Memorial Trust (for faculty and curriculum development in neurobiology) and the Sherman Fairchild Foundation (faculty development and support in computational neuroscience).

#### Program in Biological and Medical Imaging

Biological imaging includes the use of conventional and scanning electron microscopy to observe cellular and subcellular structures. The Laboratory for Computer-Assisted Microscopy and Medical Image Technology (CAMIT) is under the direction of Dr. Alan Nelson who is an Associate Professor in the Department of Nuclear Engineering and the Whitaker College. As a facility, the laboratory provides microscopy and imaging services to other investigators and their staff and is extensively involved in the development of techniques for and three-dimensional reconstruction of images derived from magnetic resonance, computerized tomography, and electron microscopy sources.

Interest in medical imaging has centered largely on the relatively recent development of magnetic resonance imaging (MRI) and positron tomography (PT). Studies have been carried out using MR instruments at the Massachusetts General Hospital and plans have now been made for an instrument to be located at the National Magnet Laboratory and to be administered and operated jointly by the Whitaker College and the Magnet Lab. in collaboration with several area medical research groups. This imaging method promises to provide unique and useful information on various diseases. Much of the interest to date has centered on diseases of the brain.

Professor Gordon L. Brownell, who has a primary appointment in the Department of Nuclear Engineering, has been extensively involved in studies on PT imaging which are carried out at the Physics Research Laboratory of Massachusetts General Hospital and in the College's microscopy facility. A new positron tomograph has been constructed and studies are underway investigating neural pathways and radiopharmaceutical distribution in mammalian brain.

Academically, the biological and medical imaging program is tied to a doctoral program in Radiological Sciences. Funded by a National Institutes of Health training grant to the College which provided tuition and stipend support for six students, doctoral candidates are admitted to the Department of Nuclear Engineering. It is anticipated that a total of twenty students will be matriculating in the program next year. Professors Brownell and Nelson comprise the faculty.

#### Program in Medicinal Chemistry and Controlled Drug Delivery System

Research in Professor Robert Langer's laboratory has led to the development of several types of polymeric drug delivery systems. One such system is the first that has the unique ability to dissolve only from the surface and still be biocompatible. By simple changes in the polymer backbone, the polymer can dissolve anywhere from one day to several years. The advantage of this and other polymer systems is that they protect short-lived drugs in the human body from degradation and enable them to be release continuously over a period of days or months in unaltered form. They are particularly useful for releasing short-acting, anti-cancer drugs used in brain tumors, as well as numerous genetically engineered polypeptides.

Studies have continued exploring the possibility of using enzymes to remove bilirubin for the treatment of neonatal jaundice, a procedure which has tested successfully in jaundiced rats. In parallel, new diagnostic tools for bilirubin are being developed based on the enzymes isolated for the jaundice treatment. Work has also been conducted on isolating and purifying substances that can inhibit the growth of solid tumors. A collagenase inhibitor has been purified from cartilage and its amino acid structure analyzed and sequenced. This substance is currently being tested for its ability to inhibit neovascularization in animal models.

Professor Langer is the holder of the Dorothy Poitras Chair in Medical Engineering in the Whitaker College through June of 1986. His primary appointment is in the Department of Applied Biological Sciences.

#### Programs in Human Biology

Dr. Monty Krieger, Associate Professor in the Whitaker College and the Department of Biology, continues his outstanding work in the study of receptor-mediated endocytosis with particular reference to the operation of this mechanism in the metabolism of lipoproteins and their relationship to atherosclerosis.

Professor Robert Rosenberg, has an appointment in the Department of Biology and the Whitaker College, as well as the Beth Israel Hospital and the Harvard Medical School. The work of his laboratory is devoted to the elucidation of a variety of molecular interactions which regulate the coagulation system and maintain vessel wall function.

The laboratory has made progress in several areas during the past year. They have shown that a specific proteoglycan whose structure is similar to the clinically utilized drug heparin is synthesized by the endothelial cells which line the blood vessel lumen. In addition, the first cDNA clone for an endothelial cell receptor which binds blood coagulation enzymes has been isolated and most of its primary structure has been determined. These two components of the endothelium function as major natural anticoagulant mechanisms of the cardiovascular system which prevent the development of thrombosis in humans. Finally,

a new blood protein has been isolated which regulates the production and maturation of platelets by the bone marrow. This observation may have important implications with regard to the role of these elements in a variety of human diseases including atherosclerosis.

#### Program in Health Policy/Management

The Program in Health Policy and Management is the only Ph.D. program of this kind in the country designed specifically for physicians and medical students. Fourteen highly qualified medical students and physicians have now been admitted to the first four entering classes which includes the new class that will enroll in September, 1986.

Under the direction of Dr. Stan Finkelstein, this program is strongly interdisciplinary, drawing upon faculty from the Sloan School of Management, and the Departments of Economics and Political Science, with the goal of providing training for physicians in the complexities of health care delivery. The graduates of this program will have competence in the management and economics of health care delivery, as well as an awareness of the political consequences of making decisions in the area of health. The first three classes have performed at a very high level and have been very positive about their educational experience. Support for the program and students is provided from funds granted to MIT by the Henry J. Kaiser Foundation.

#### Other Activities

Three seminar, examining new and exciting areas in the field of neuroscience, were held during the academic year as part of our Distinguished Lecture Series in the Brain Sciences which we began in 1984. As in the past, the lectures and receptions that followed were very well attended by the Institute community.

Our Neuroscience seminar luncheon series resumed in September and was again a great success. Convening at least three times a week, presentations by both invited and in-house speakers were held throughout the academic year to promote exchange and exposure to the latest developments in the field of brain sciences.

Nine pre-doctoral fellowships were again awarded this spring to students working with faculty in the Whitaker College. The funds for these awards, which provide both tuition and stipend over a twelve month period, are generously provided by the Surdna Foundation, Edward J. Poitras Fellowship funds and the Whitaker Health Sciences Fund.

One postdoctoral and nine predoctoral fellowships were awarded from funds received from the Sherman Fairchild Foundation to researchers involved in computational neurosciences at MIT. Ten additional awards have been made beginning in September, 1986.

#### Faculty and Staff

Dr. Monty Krieger and Dr. Alan Nelson were promoted to the rank of Associate Professor, effective July 1, 1985.

Dr. Monty Krieger was named the first recipient of the Latham Family Career Development Professorship for his outstanding contributions to both education and scholarship in biochemistry.

Dr. Robert Mann, Whitaker Professor of Biomedical Engineering in the Department of Mechanical Engineering was named Director of Bioengineering Programs in the Whitaker College. This appointment will become effective July 1, 1986.

I am honored to have been elected to the National Academy of Sciences this year.

EMILIO BIZZI, M.D.

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# Associate Provost for Educational Programs and Policy

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## Office of the Dean for Undergraduate Education

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### INTRODUCTION

Newly established by recommendation of the faculty and by design of the new Provost, Professor John Deutch, the Office of the Dean for Undergraduate Education (ODUE) began on July 1, 1985, to discharge an ambitious mission:

- To address with the academic school deans the obstacles and discouragements faculty and departments identify as impediments to serious dedication to high quality teaching, advising, and other forms of interaction with undergraduates.
- To promote a climate of "Why not?" and an excitement for experimentation and possibility.
- To establish an accepted ODUE style permitting straightforward reminding of the faculty and departments of their responsibilities in undergraduate education in a steady, sensitive manner.
- To promote and guide Institute-wide review of academic program, educational content and rationale, balances of emphasis between research and instructional activities and between undergraduate and advanced education activities. The most obvious manifestation of review is the interlocking array of school, Institute, and departmental committees now underway. Quieter efforts and in different formats and schema must also take place, ranging to the individual faculty member -- who must undertake personal internal review of his/her professional dedication and goals within this institution.

There are two fundamental issues underlying this mission. The first pertains to the content, form, and character of the undergraduate academic program. The faculty seeks to regain broadly-based agreement about the purpose of the undergraduate academic program and its intended audience. The second issue is that of achieving a proper balance of faculty commitments between research enterprises, including postdoctoral education and graduate education, on the one hand, and undergraduate education, including nonclassroom encounters, on the other. Both of these issues will require as much as a decade or more to address and are not amenable to curricular decisions or to academic legislation.

And, both of which are too simple in that they treat the symptoms, not the source of them. The nub of things is MIT's own culture. It is here that the Institute's strengths and uniqueness lie. And it is here that the viscosity surrounding change may be high.

ODUE operations and activities in 1985/86 were directed toward laying a foundation upon which to build.

MARGARET L.A. MACVICAR

### THE NEW COMMITTEE ON THE UNDERGRADUATE PROGRAM (CUP)

By faculty vote in spring of 1985, CUP replaced the Committee on Educational Policy, CEP. The new faculty committee is half the size, and charged to concentrate most of its attention on longer-term issues relating to the nature and quality of the undergraduate academic program and the overall undergraduate experience. A major goal for this year has been to begin the Institute-wide efforts needed to achieve a common understanding of undergraduate education at MIT -- what MIT is doing well and not as well, and what MIT should be doing in the light of society's needs and MIT's particular strengths and limitations.

Much of the CUP's fall term agenda -- through presentations/discussions by various CUP members and guests, as well as a great deal of background reading -- focused on preparation for two days of intensive meetings in January. These intensive meetings were aimed at reaching, as a group, some agreement on the fundamental objectives and characteristics of an MIT undergraduate education (including identification of areas where there is significant disagreement) and on significant problem areas that constitute the future agenda of CUP.

Out of the January meetings emerged the beginnings of two major, but related, directions. First, a preliminary statement was prepared of some assumptions and principles about the nature, character, and priority of MIT's undergraduate education around which the CUP had begun to coalesce. A revised version was distributed to the Faculty in March. Attention was given to learning styles and formats, the priority of undergraduate teaching and advising, and the role of General Institute Requirements in an undergraduate degree program. The purpose in distributing the report was to begin a process of communication and iteration with members of the MIT academic community -- toward the goal of developing a more broadly shared Institute-wide consensus on these issues.

Second, a set of agenda issues and a tentative plan for moving forward on them emerged in the form of a working document, which continued to be refined during the term. Some of the most important problem areas to address, summarized in broad terms, are the following:

#### Nature and Character of MIT's Undergraduate Education

Articulation: a concept of General Education as definition for the General Institute Requirements -- responsibility for which is shared by all Faculty, across all schools; the appropriate balance and relationship between General Education and the Professional Specialization components to achieve a coherent, broad education; the nature and rationale of the broader context for oversight and coordination needed for the General Institute Requirements and the Freshman Year.

#### Learning Styles and Formats for the Curriculum

1) Encouraging more opportunities for one-on-one student/faculty encounters, and fostering a student orientation toward "making MIT your own". 2) Exploring new advising initiatives and the question of accountability for advisors. 3) Exploring questions about pedagogy and learning styles and how students learn best, e.g., making the undergraduate program student-centered rather than content-centered, developing students' own educational goals/values, and allowing for diversity among students in patterns of adaptation and learning style. 4) Ensuring that the impact of Project Athena on the nature and character of undergraduate education is adequately explored. 5) Determining how IAP can become more educationally rich and useful for our students. 6) Supporting efforts to strengthen a student culture centered around ideas, growth, and vision that interacts positively with the educational program. 7) Addressing the tone set by the freshman year in establishing students' approach to MIT (R/O, freshman Pass/Fail, appropriateness of professional subjects, etc.). 8) Encouraging the perspective, through experiences in every subject offered at MIT, that writing and the written construction of arguments are essential tools in the process of conceptualization and learning.

#### Relative Priority of Undergraduate Education Amongst Other Faculty Commitments

1) Examining leverage points for improving and rewarding good teaching, curriculum development efforts, dedicated advising, and other group and one-on-one interactions with students. 2) Exploring the necessity of intervening in the ratcheting research volume/graduate student/postdoctoral research spiral by policy directions.

While the discussions of shared assumptions and long-term agenda have been underway, the CUP has also been at the crossroads of educational review discussions that have been initiated this year in the four committees described below. A major priority over the next 12-18 months is to bring to closure this review process. A subgroup of CUP will be undertaking an intensive work session this summer to take a first crosscut aimed at reconciling the results to date of the deliberations of these ad hoc committees.

MARGARET MACVICAR, Dean, Chair  
ALAN GRODZINSKY, EECS  
JAMES MUNKRES, Mathematics  
EDWARD ROBERTS, Management  
ROBERT SILBEY, Chemistry  
PAULINE MAIER, History  
DAVID WILEY, Executive Officer

JACK L. KERREBROCK, School of Engineering  
JONATHAN GRUBER, '87  
CAREY RAPPAPORT, Graduate Student  
SAMUEL JAY KEYSER, Ex Officio  
SHIRLEY MCBAY, Ex Officio  
CARL LACOMBE, Guest

#### REVIEW OF THE UNDERGRADUATE ACADEMIC PROGRAM

Charged and established jointly by Dean MacVicar and Ann Friedlaender, Dean of Humanities and Social Science, the Committee on the Humanities, Arts, and Social Sciences Requirement (HASS) is developing a proposal for a new HASS Requirement, with particular emphasis on the Humanities Distribution component. An interim report was disseminated to the faculty for discussion and response in February. The Committee's final report is now complete and will be available widely for debate next fall.

PAULINE MAIER, History, Chair

The School of Science Education Committee, constituted by Gene Brown, Dean of Science, is assessing the effectiveness of the required core science and mathematics subjects and reviewing the Science Distribution and Laboratory Requirements. A preliminary, internal report was issued by the Committee in May addressing the quality of teaching in the core science subjects and proposing changes in the Science Distribution Requirement. After further deliberations on remaining issues, the Committee will issue a final report in the fall.

ROBERT SILBEY, Chemistry, Chair

The Commission on Engineering Undergraduate Education is conducting a comprehensive review of MIT's undergraduate engineering program, including the engineering curricula and those aspects of the Institute's core and of the Institute's environment that influence engineering education. This examination extends across the School of Engineering's eight departments. A preliminary statement of agreed-upon goals and objectives of an MIT engineering education for undergraduates was accomplished by January. The Commission will issue its first formal report this coming fall.

JACK KERREBROCK, Associate Dean of Engineering, Chair

Following its chartering by Dean Friedlaender, the Committee to Design an Integrative Curriculum in the Liberal Arts has proposed an integrative program that establishes dual competency in a technical discipline (science or engineering) and a humanities, arts, or social science discipline. The Committee's final report will lead to the establishment of a new task group, charged with devising an implementation strategy and proposal to CUP for an educational experiment.

LEO MARX, Science & Technology, Chair

The chairs of the first three committees sit on CUP as members appointed by the Dean for Undergraduate Education. During the year, the various review committees have made periodic reports to CUP, which have been invaluable in sharing ideas, as well as identifying and addressing differences in points of view and directions on various issues. The CUP has provided guidance to these committees as it reviews the recommendations for change in the academic program that are emerging from the review process.

#### THE CONCEPTION OF THE OFFICE

A small, "lean", office is envisioned. Programmatic components such as support to the Committee on the Writing Requirement, the Undergraduate Research Opportunities Program (UROP), departmental and freshman year academic program support, and curricular innovation and oversight are in the process of being brought together into an integrated enterprise.

To this end one new staff position was created this year -- Assistant Dean for Curriculum Support. By the end of the year, these activities will be organized into an umbrella hospitable to undergraduate educational innovation built around individual student initiative, undergraduate research, research seminars and colloquia for/by students, writing seminars, freshman year academic experimentation, and encouragements to faculty and departments.

Strong interrelationships are being forged with the freshman alternative programs ESG, Concourse, and ISP. In particular, their staff have been invited to participate in studies and projects of the ODE. Collaborative efforts with ODSA -- especially with the UASO and OME sections -- are expected to emerge over the coming year.

During 1985/86, ODE had access to crucially needed expertise in social and educational research required for the Dean's initial ventures by borrowing on the excellent Executive Officer staff support to CUP in the person of Dr. David Wiley. However, with the imminent departure of Dr. Wiley to head the Undergraduate Academic Support Office (UASO) as of July 1st, CUP will no longer have this level of support, which could be a drawback in the coming year's effort to move along the Institute's educational agenda with respect to the academic reviews underway and the pending agenda concerning the core and freshman academic programs. However, it may be possible to develop the needed expertise in UASO, the Planning Office, and the Registrar's Office.

One other need of ODE is space. This year two staff were housed temporarily in Building 7. This summer the two staff will move to Building 20, but again, into temporary space. The need for ODE to be consolidated in permanent space is a problem to be solved this coming year. A congenial area or suite comprising approximately 2000-2500 square feet is required.

## PROGRAMMATIC HIGHLIGHTS

### Curriculum Support

Margaret Richardson joined ODU in the fall as Assistant Dean for Curriculum Support, with responsibility to support departmental academic programs and the freshman year academic program. A pilot effort to coordinate the student populations of 18.01 Calculus and 8.01 Physics I recitations fall term, and 18.02 Calculus and 8.02 Physics II recitations spring term, was undertaken in order to explore the prospects for meaningful coordination of content, pace, and style of these two General Institute Requirement mainstays. Responses by participating instructors, the two departments' leaderships, the Registrar's Office and the Dean of Science have laid the foundation for a more formal experiment in fall 1986.

The second major activity of Ms. Richardson this past year was that of secondment to the Office of the Dean for Student Affairs (ODSA) and the Associate Provost for Educational Programs and Policy to provide experienced staff support for the new Institute Colloquium effort and to participate in the development of the new freshman seminar initiative scheduled for fall 1986.

### Committee on the Writing Requirement (CWR)

Previous to this year, the Committee existed in relative isolation administratively. Inclusion of the Committee's sphere of activity within the overall ODU framework will now provide its staff member, Bonnie Walters, Coordinator, logistical resources including clerical support, as well as a collegial base.

### Undergraduate Research Opportunities Program (UROP)

The Undergraduate Research Opportunities Program's (UROP's) sixteenth year has been one of change and new beginnings. In the spring the program received its first gift toward endowment. Groundwork has been laid for UROP's central role in the newly emerging Office of the Dean for Undergraduate Education. It has also been a demanding year: staff changes resulted in temporarily reduced staff, while at the same time, interest in the program and participation were higher, once again, than in previous years.

### Educational Video Productions (EVP)

Educational Video Productions (EVP), formerly EVR, underwent review this year as to its mission, market, effectiveness and potential. Following a broadly participative process, EVP was terminated on June 30, 1986. Dr. Edwin Taylor, Director, will return to the Physics Department as Senior Research Scientist.

A new Graphic Arts Video Services section is authorized to operate for two years in order to achieve a financial break-even, which will be a major criterion for long-term continuance of the new section.

### Project Athena Study Group

After a start-up period prior to this year to familiarize themselves with the issues, the Study Group moved thoughtfully to a program of studies and research directed toward enlightening the Project Athena Executive Committee, CUP, the Provost's Office, and the MIT community on issues and findings relevant to understanding the Project Athena venture now underway. Two major studies are in progress. These will be reported next year.

The Study Group continues to meet as a Forum on computers and education issues. A third undertaking may emerge -- concerning the assembling of an archival database about Project Athena. Meanwhile, communication between the Study Group and Project Athena's leadership still requires improvement. In particular, the Study Group's insights and research results must be germane to -- and be regarded as germane to -- the major decisions facing Project Athena less than 18 months from now.

JOHN DE MONCHAUX, Dean of Architecture & Planning, Chair



#### OUTREACH AND SUPPORT TO DEPARTMENTS AND PROGRAMS

Activities during ODU's first year included a number of efforts to support programs or projects that could best assist departments and their faculty in the pursuit of an improved educational experience for them and their students. These efforts were principally the responsibility of Assistant Dean Margaret S. Richardson, who joined ODU on a part-time basis in December, 1985. Activities in this area include the following:

##### Math and Physics Departments' Linking of Freshman Recitation Sections

During both 1985-86 terms, sections of freshman math subjects (18.01 in the fall and 18.02 in the spring) were paired up with freshman physics sections (8.01 and 8.02), so that students who were in one of the math sections were also attending a "linked" physics section. One of the original goals of this effort was to provide students an opportunity to see each other more frequently in classes and thus become more comfortable with each other, creating a climate where it was easier for the students to interact with the instructor and each other. In this way linked recitation sections were an attempt to create a classroom atmosphere much like that in the alternative freshman programs (Concourse, ESG, and ISP). More importantly however, the paired math and physics instructors were encouraged to take advantage of the pedagogical opportunities made possible through this arrangement (e.g., attend each other's classes, share syllabi and texts, discuss the performance of students they had in common, collaborate on the teaching of the subject matter, etc.). The opinion of participating students and instructors about the utility and success of linked recitation sections has been mixed, particularly with respect to the effort during the spring term, but based on generally positive feelings about the potential of the program -- particularly during the first term of the freshman year -- Dean of Science Gene M. Brown has recommended that departments continue with the experiment for another academic year. With the assistance of the ODU, plans are underway to coordinate an improved form of core department lecture and section collaboration during the coming academic year which will include Chemistry Department participation.

This limited effort to link freshman recitation sections has provided exciting opportunities for the departments of Mathematics, Physics, and Chemistry to begin discussions about the current and future freshman year science curriculum. Professor Benson R. Snyder participated in aspects of the activity, as well, taking the opportunity to do classroom observations and oversee a number of student interviews. In addition, the activity has provided the catalyst to bring together people in the Registrar's Office, the core science departments, and the ODU to discuss ways to improve not only the linked scheduling process, but also the way freshmen are assigned to both lectures and recitations. Recent discussions have led to a decision to "link" freshmen in their first term calculus and physics lectures as well as their recitation sections. As a result, beginning in the fall term, the large number of 18.02-level students enrolled in 8.01 will be assigned to a different lecture section than those students with weaker mathematics backgrounds.

The excitement of the potential of the current cooperative spirit among the departments must be tempered by the fact that all such activities require that additional time be invested by the faculty and other instructors involved in the effort. It is clear that, although instructors endorse the idea of a more integrated and collaborative program in the freshman year, most do not feel they can comfortably spare the time to be involved in something which demands additional creativity in teaching. The challenge for ODU will be to nurture the excitement of interested departments and instructors about the value of interdepartmental collaborations and to provide the resources and encouragement to execute them.

##### Publication of a Resource Guide for Academic Officers

A rather thorough review of the structure and personnel involved in each department's undergraduate education program was begun early last fall by Dr. Jeffrey Meldman, Associate Dean in the Undergraduate Academic Support Office, completed by Margaret Richardson, and distributed widely to departments, faculty committees, some student groups, and administrative offices. The document, "Departmental Undergraduate Committees and Curriculum Support," has turned out to be a useful compendium of information for the whole host of people and offices involved in the undergraduate program, including providing the opportunity for department officers to obtain information about the educational committee structure and plans taking place in other academic departments. As a result of its success, the guide will be updated and re-issued by ODU on an annual basis.

##### Support to the Freshman "Core Curriculum Group"

We have assumed responsibility for supporting the regular meetings of the faculty and administrators associated with the freshman program (traditionally referred to as the "core group"). During the spring term, Dean of Science Gene M. Brown chaired the first gathering in four years of this group.

### Support to a Student-Run Subject Evaluation

Since it is clear that departments and faculty are interested in a regular and creditable evaluation of subjects and instructors, we are assisting with the effort to establish an Institute subject evaluation that involves students in key ways but that exists as a process whether or not students take an active role during any given year. ODU provided the initial funding for a new effort involving the student Course Evaluation Group and is working with staff in the Undergraduate Academic Support Office and in the schools to develop adequate support to the student activity as well as explore the future directions of MIT's subject evaluation process.

### Creation of a New Undergraduate Seminar on Educational Policy and Reform

In response to a number of student requests that they be given more substantial opportunities to involve themselves in the current educational reform process, an undergraduate seminar was offered during the Spring Term under the auspices of ODU and the Program in Science, Technology, and Society. STS S08 -- Student Perspectives on Educational Policy and Reform -- led by Professors Carl Kaysen and Benson Snyder, was attended by 14 students and a number of faculty and staff, and gave students a chance to delve into some of the key issues and problems associated with MIT's educational program. Each week a different faculty member -- usually someone noted for expertise in undergraduate policy or pedagogy -- was invited to a class convened by one of the students. The seminar provided an excellent springboard for these students to continue their interest in projects scheduled during the coming summer, since they are now much better acquainted with many of the people, problems, and possibilities at MIT.

The goal of these and other projects has been to catalyze educational awareness, communication, and activity around the Institute. Be it working with Graphic Arts to develop a more effective student picture distribution system, with faculty who would like to improve the exposure freshmen have to experimental experience, or with the planners of R/O Week to give new students a better idea of the range of opportunities at MIT, our efforts are intended to empower a "can do" attitude on the part of everyone at the Institute.

MARGARET S. RICHARDSON

## INTRODUCTION

We have focused on Phase Two of the Requirement this year because the Class of 1987 is now in the process of completing it. These are the first MIT students to accomplish that task, and many factors have come graphically into play as they have gone about it.

The students we encounter are aware of, even enthusiastic about the Requirement. They are also frustrated, particularly frustrated in trying to satisfy Phase Two. They report that opportunities for professional writing within their departments come too late (i.e., senior year) to allow for Phase Two submission. Ironically many of the best opportunities students have to write in a professional manner come not from MIT subjects but from outside cooperative arrangements such as the Course VI-A Program. Although the School of Engineering does provide other opportunities for professional writing within a number of intra-departmental subjects, other schools may not. A few Courses offer only limited opportunities other than the senior thesis. Faculty members assert the importance of writing but cite their own workloads as the impediment to finding time to judge the quality of their students' professional writing. Our task is to address and to resolve some of these conflicts. We are convinced that we can.

The paradoxical interplay of these factors affects our two primary goals: to improve the quality of MIT student writing and to help students move through the two phases of the Writing Requirement in the manner which best suits them. Particular students -- especially transfer students -- find themselves caught between these goals and the issues surrounding them. Other goals complicate the search for a good resolution: namely, our desire to set, maintain, and communicate acceptable standards of writing to students, faculty, and the MIT community and to inform all of these people about the purpose and nature of the Writing Requirement.

Keeping in mind this swirl of goals and issues, the Committee has determined upon a Strategic Plan to implement both phases of the Requirement. It has already been of great use as we plan for moving the Class of 1987 through the last stage of the Requirement. A major part of this scheme includes numerous meetings with departments and administrative staff to review progress in Phase Two implementation and to help them prepare to accept transfer of primary responsibility for this phase to the departments.

## PAST AND PRESENT ACTIVITIES

### 1) Freshman Essay Evaluation

Of the 970 freshmen who took the 1985 Freshman Essay Evaluation, 690 received a PASS or MARGINAL PASS. The most popular of the four Phase One options, the essay evaluation introduces students to the Writing Requirement and incidentally allows us to help them adjust to MIT. The counseling which evolves from these first meetings continues throughout the freshmen year for many students as they satisfy Phase One through other options, such as the five-page paper or one of the expository writing subjects.

Reading the essays and distributing the results quickly can now be handled well through the help of outside readers and temporary student help. We also rely heavily on our Institute Readers, a dedicated group of faculty and staff from all over the Institute who take on the reading of the 200-300 essays from the second and third evaluation dates. The spirited, swift good work of all these volunteers makes the Freshman Essay Evaluation an annual joyous event.

### 2) Report to the Faculty on Phase One

After consulting with the Faculty Policy Committee and individual members of the faculty and administration, we reported to the Faculty on Phase One on April 16, 1986. Stressing the effectiveness of this phase, we recommended only one minor change: narrowing the MARGINAL PASS category to avoid the occasional false sense of security some students develop about their writing when they receive such a grade.

In 1986-87 the Committee will review the full Requirement with emphasis on Phase Two and will report to the Faculty in the Spring of 1987.

### 3) Meetings with Institute Departments

Our second round of meetings with departments has centered around writing standards and on the need to provide many writing opportunities for students prior to their attempting 10-page papers to satisfy Phase Two. As the realities of the Writing Requirement impinge upon them, faculty members have become genuinely concerned about their students' writing. There is the sense of grappling together to arrive at ways to help their students and, in a few cases, their colleagues. We often use faculty members to re-read papers in cases of divergent opinions. Doing that has persuaded some faculty to reexamine their own standards and to set up and to distribute to their students criteria and sample formats for them to follow.

Not all students will satisfy Phase Two through papers, of course. Our discussions have also included mention of existing writing subjects, including those jointly taught by the School of Engineering and the Writing Program, as well as the formal advanced subjects in science and engineering writing developed by the latter program. We hope that departments might eventually create their own writing-intensive subjects as they assume the work of Phase Two.

### 4) Meetings with Registrar and the Committee on Academic Performance

We meet periodically with Associate Registrar Ronald P. Smith and his staff to iron out the occasional kinks in our reporting system. Integrating the Writing Requirement into the various Registrar's reports has, on the whole, been accomplished smoothly. We also met with the Committee on Academic Performance to inform them about Phase Two. The fall registration material for seniors will contain a letter from the Chairman of that committee reminding these students of their need to satisfy both phases of the Writing Requirement.

This letter reflects our concern the students who have yet to complete Phase Two. While we expect heavy completion of the Requirement during the Fall Semester, we must remain alert to last-minute crises such as we experienced just at the end of this 1985-86 academic year. We have set March 1, 1987 as the deadline for receiving Phase Two papers from graduating seniors. Prior to that date we will send all the departments lists of those of their majors who have not completed the Requirement. The Committee will also send seniors a letter reminding them to complete the Requirement.

### 5) Statistics

These are the latest statistics on Requirement completion for the Classes of 1987, 1988, and 1989.

<u>Class</u>	<u>Number in Class</u>	<u>Phase One</u>	<u>Phase Two</u>
1987	1125	1041	335
1988	1185	1052	187
1989	1067	894	4

### 6) Committee Membership and Staff

During academic year 1985-86 Professor Kenneth Hoffman chaired the committee for the third year. This year's Committee members included Professors Michael Driscoll, Anthony French, James Keck, John Van Maanen, Suzanne Flynn, and, *ex officio*, Professor James Paradis and Dean Margaret L.A. MacVicar. Ted C. Johnson and Christopher Saito served as our two student representatives.

From its inception the Committee has depended upon its Coordinator, Bonnie Walters, to organize implementation of the Requirement and to supervise students' progress through it. Ms. Walters has been aided ably by several MIT student workers, including Alexandra Page and Corinne Wayshak. Other MIT students have helped us out on an as-needed basis.

### 7) Student Input

Beyond the vital help our student workers provide come the contributions of the many, many MIT students affected by the Requirement. We try to incorporate their suggestions when possible and always appreciate their comments and advice. As part of our Phase Two Review we will survey several groups of students, a task in which our student committee representatives will involve themselves.

#### FUTURE ACTIVITIES

With our incorporation into the Office of the Dean for Undergraduate Education, the work of the Requirement staff will broaden considerably. The linking of key offices, such as the Undergraduate Research Opportunities Program, to that of the Writing Requirement will stimulate fruitful collaboration and provide students with a surer notion of the importance of writing within a "real-world" framework. Juxtaposing these and other student-oriented offices fits the changing concepts of MIT education for the 1990s and beyond. Our search for a permanent home has ended. We look forward to joining the Dean's office not merely for the permanence it will provide but for the collegiality and inspiration that it will bring.

The academic year 1986-87 will test the strength of the Requirement as well as the strength of the Class of 1987. We have been impressed with these students' efforts to comply with and to complete the two phases of the Writing Requirement. We very much look forward to helping them achieve one of the essential aims of an MIT education: to graduate clear, effective communicators of the knowledge they have worked so hard to gain.

KENNETH HOFFMAN  
BONNIE WALTERS

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## Undergraduate Research Opportunities Program

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Student participation in undergraduate research set another record in the fall term with a six percent increase in total numbers; participants this spring matched spring '85 participation. It seems evident that the majority of students now choose to do research for pay during term time, as percentages continue to move farther in that direction (66 percent in fall '85 choose pay, 57 percent in fall '84; 66 percent in spring '86, 58 percent in spring '85), a trend first observed as tuition began its steep rise several years ago. A survey of faculty participation over a three-year period completed early in spring '86 (but not including figures for academic year 1985-86) indicates continued faculty participation of over 50 percent. In the last fiscal year faculty contributed student wages from sponsored research reached nearly \$3 million. This fiscal year a figure of well over \$3 million is expected. Pressures for direct UROP support were exceptionally strong. Fortunately, these were offset by gifts of income, one of \$20,000 from the Lord Foundation, one of approximately \$10,000 from the Admiral Luis de Florez '11 fund. Wages providing direct UROP support were kept at \$4.50 an hour in the summer of '85. Student financial needs, plus the continuing disparity between the Institute minimum wage of \$5.50 an hour and UROP's \$4.50 an hour rate, prompted us to raise the base UROP wage to \$5.25 an hour in fall 1985. An increase of \$20,000 from Institute General Funds permitted this increase for the academic year. It did not cover the overall increase in participation, nor the increased proportion of students choosing to participate for pay.

A gift of 4,000 shares of W R Grace common stock from alumnus Ralph Evans, Class of '48, provided the program with its first step toward what we hope will be full endowment. A pending proposal may yield further endowment support from another source.

Eleven award funds help extend UROP financial support and encourage and reward outstanding effort. Eight undergraduates were awarded Civil Engineering Traineeships; six received support for original engineering design from the Clapp and Poliak Engineering Design Fund; two won Class of 1970 Awards for socially-oriented research; three won Class of 1972 Awards for research that improves the quality of life through its impact on society and/or the environment; eleven students were supported by the Admiral Luis de Florez fund; two students received McCormack UROP Awards given for research relating to technology and its application to societal problems; six received New England Life UROP Awards, granted to support undergraduate research on health-related issues; Sea Grant gave awards to twelve undergraduates involved in ocean and ocean-related topics; MIT Chapter of Sigma Xi gave materials and services support to four undergraduate researchers. The Joel Matthew Orloff UROP Award for outstanding ability and creativity in physics-related research was given this year to Thomas R. Junk, '88. Ranu Gupta, '87, M. Anjali Sastry, '86, and Rajesh Mehta, '86, won Eloranta Summer Fellowships. A winner of an Eloranta Summer Fellowship in 1985, Brenda Golianu, was granted additional funding by Eloranta Fellowship sponsor Dr. Edwin H. Land through the Rowland Foundation to finish her work in the 1986 summer. UROP was honored by the decision of the Class of 1972 at its 15th reunion to endow a UROP fund with a minimum of \$15,000 so that the Class of '72 UROP Award may continue. Next year the Dean Horn Sea Grant Award for undergraduate research joins the other UROP awards.

Undergraduates shared their research experiences this year at alumni clubs in New Haven, Connecticut (Ranu Gupta, '87, and Mark Filerman, '88), Minneapolis, Minnesota (Jack Leifer, '87, and Lindy Elkins, '87), and Cleveland, Ohio (Scott Martin, '87). Joy Hussain, '86, was invited to speak to a meeting of newly admitted students.

Inquiries about UROP were exceptionally frequent this year. At the request of CHEMTECH, a chemical industry journal, an article about the program is in preparation. University inquiries were greater in number than ever. We have talked with, been visited by, and exchanged correspondence with educators from Clarkson University, Dartmouth, James Madison University (Virginia), Harvard University, Mills College (California), UCLA, University of Minnesota, University of Colorado (Boulder), University of New Hampshire, SUNY Stonybrook, University of Maryland, Tufts, Coventry (England) Polytech. Associate director Norma McGavern spent a day at New York University at their invitation discussing UROP philosophy and policies. We eagerly await word of the results of these various endeavors.

Discussions and the beginning of cooperative ventures have begun with other members of the new Office of the Dean for Undergraduate Education. Bonnie Walters, coordinator of the Writing Requirement, and Margaret Richardson, assistant dean for undergraduate education, are planning moves to neighboring offices in building 20. The mutual encouragement of good writing, as evidenced in UROP proposals and research papers, should be one byproduct of our cooperation. Our "annex" space in room 148, officially UROP's at last, will be a target of renovation shortly, and will provide shared space as a conference room, library, seminar room, writing requirement space, and will serve as kitchenette/lounge as well. Storage facilities, office supplies and equipment will be shared, it is foreseen, and space arrangements will remain flexible as job functions and physical space requirements change. It is hoped that the accumulation of people sharing adjacent space in building 20 such as the staff of the Integrated Studies Program, will be of immense mutual benefit to the Institute, to students, and to the liveliness of the programs served.

The availability of the services of a free lance photographer this spring, Laurie Sokolsky, gave UROP an opportunity to undertake an extensive photographic documentation of current--and typical--UROP projects in a wide variety of areas. Results will be photographs for a future brochure, for bulletin board displays, and pictures to share with other MIT offices which frequently make such requests.

Staff member Maureen Horgan, with assistance from Jae Sang, '88, oversaw our first successful year of UROP DIRECTORY preparation via office computer. This was made possible by our purchase earlier in the year of our second IBM, with hard disc, to which we transferred all our record and data keeping functions. Mr. Sang fine-tuned our software, and is now working of complete documentation and further refinements. We acquired a laser printer in the spring. Future computer projects include computerizing UROP project descriptions and TECH TALK columns.

In November 1985 assistant director Michelle Lamarre began a leave of absence to complete an undergraduate degree. Ms. Horgan was promoted in spring to assistant director, and continues at UROP half time while pursuing a music career. Greg Smith continues to visit many student researchers on site as special projects coordinator. Ms. McGavern offered the undergraduate seminar on making oral presentations for the third fall semester. Lisa Merritt, our senior secretary, left in September to study for an MBA degree. Dianne Brooks joined us as staff assistant in September and was promoted to senior staff assistant in the spring. She gave birth to a daughter in January, and was on leave for two months. Ms. Brooks made sure we had a well-trained cadre of undergraduate office helpers who helped us make our way through this busy time: Michael Berube, '89, Scott Kitchen, '89, and Jennifer Munde, Wellesley '87. Margaret Mubiru-Mosoke joined UROP for several months as assistant director and left at the end of April. We were very happy to be able to appoint a new assistant director, with redefined responsibilities, in June. Jane Sherwin is currently Secretary to Harvard University's Advisory Committee on Shareholder Responsibility. Ms. Sherwin will work closely with Ms. McGavern on student proposals, funding, and UROP policy issues. She will begin June 30. The program reports to Professor Margaret L. A. MacVicar, dean for undergraduate education and UROP program director.

NORMA G. MCGAVERN  
MARGARET L. A. MACVICAR

MIT Educational Video Productions is the video consulting group for the Institute. Faculty, students, and staff come to us for advice on the uses of video in teaching, research, coursework, documentation, artistic creation, and performance. In addition to a great deal of general advice in response to requests for help, our activities fall naturally into three categories. For each of these categories, some examples of individual projects are listed.

1. Educational Projects.

Use of our production and editing facilities by Film/Video classes and Master of Arts in Visual Studies students. Physics help sessions recorded for cablecast on MIT cable system. Consultation with MIT-Woods Hole group on transmission of classes between the two locations. Videotaped summer course on power electronics and associated experiments for EE/CS Lifelong Learning Program, laboratory experiments for presentation as part of RLE summer course, several short training courses given by Project Athena, courses for Department of Urban Studies and Planning, presentation of the play "Galileo" in German by Advanced German Class. Continued development of videodiscs for teaching Spanish and French under an Annenberg grant to Foreign Languages and Literature.

2. Requested Videotape Productions.

The following were recorded and cablecast live to Lincoln Laboratories, Harvard University, and Massachusetts General Hospital: seminars in VLSI, Biology, and Research Laboratory of Electronics; EE/CS colloquium series. Recorded Neils Bohr Symposium at the American Academy of Arts and Sciences, "Star Wars" debate in Kresge Auditorium, Colloquia and Dedication Ceremonies of the Wiesner Building for Institute archives and for Japan Broadcasting (NHK). Press conference videotape of artificial hip developed by MIT and Massachusetts General Hospital. Videotaped quarterly reports of Composites Group in Mechanical Engineering to its research sponsor, Lester Thurow commentaries for PBS Nightly Business Report, series for Architecture Department "Architecture of Substance." Produced two fundraising videotapes for the MIT Alumni Office. Videotaped presentations by visiting artists for the Committee on the Visual Arts. Supplied footage of MIT for outside news networks.

3. Documentaries on Research.

Professional quality video presentations of research projects at the Institute. Examples: Mechanical Engineering: Prototype Flexible Assembly Cell; Biology: Oncogenes; Civil Engineering: Project Athena Computer Aided Teaching System for Structural Engineering; Chemical Engineering: Surface Fluorination of Polymers; MIT Museum: Subminiature Vacuum Tubes; MIT Computer-aided Design Laboratory: General Description.

On July 1, 1986 MIT Educational Video Productions will be disbanded. Service video functions will be transferred to MIT Graphic Arts.

EDWIN F. TAYLOR



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## Office of the Dean of the Graduate School

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The Annual Report of the Dean of the Graduate School (DGS) appears in two parts. The first is a set of separate narrative reports by the Dean and the two Associate Deans. The second is a set of tables of statistical information for the Graduate School. These are presented in formats similar to those used in past years in order to facilitate comparisons over time.

### DEAN OF THE GRADUATE SCHOOL

At the beginning of the past year, the Dean of the Graduate School (DGS) entered into a new reporting arrangement designed to bring together several closely related activities which had until then been administratively separated from one another. Specifically, the Dean for Student Affairs (DSA), the newly established Dean for Undergraduate Education (DUE), and the DGS were brought together in a coherent organization reporting to the Associate Provost for Educational Policy Programs, Professor S.J. Keyser. The organization has quickly come to be known as "the Keyser team". The many implications of this new organizational structure are discussed elsewhere in the report of the Associate Provost. Here, it is sufficient to note that the new structure has given the DGS an opportunity to participate much more effectively in the general planning of educational policy at MIT, especially in those areas where issues of graduate education, undergraduate education, and student quality of life, all come together and impact on one another.

One direct outgrowth of the activities of the Keyser team was a renewed and expanded attention to the issue of graduate student enrollment or, more precisely, the continued growth in that enrollment. Data on both graduate and undergraduate enrollments for the last 25 years were assembled and evaluated. These data showed an unchecked growth of graduate enrollment at about 3 percent per year in recent years, during which time undergraduate enrollment was nearly constant. Consequently, the ratio of graduate to undergraduate enrollments, which for many years had been relatively constant at a value of about 0.85, has now grown rapidly to its current value of 1.08 (G=4920, U=4541, G/U=1.08). Moreover, since 1968, graduate enrollment has grown at a rate which is more than three times the faculty growth rate and twice the undergraduate growth rate.

From its review of these enrollment data, the Keyser team concluded that they raised major policy questions which should be addressed at various levels within MIT. These included questions about the impacts of such growth on the quality of life for both graduates and undergraduates, the desired relative sizes of the two student populations, and the mechanisms available for regulating the graduate enrollment desired. We have also begun to try to understand better the driving forces which produce these enrollment trends and have already determined that the forces, and therefore the impacts and opportunities for control, vary markedly across the schools and departments.

Our principal action during the past year was to bring the enrollment data and our concerns about those data to various fora for discussion and reaction. These fora included the Academic Council (AC), Faculty Policy Committee (FPC), Committee on Graduate School Policy (CGSP), and the Graduate Student Council (GSC). The student newspaper, *The Tech*, also carried a front-page article which called public attention to the data and our concerns. While no formal plans were adopted for regulating graduate enrollments, it should be noted that attention drawn to the issue has resulted in voluntary departmental decisions to make reductions in cases where there was a clear need to do so.

Clearly related to the issue of graduate enrollment is the issue of graduate housing. The stock of MIT housing for graduate students has not nearly kept pace with the number of graduate students. As a result, our oft-stated goal of providing MIT housing for 50 percent of our graduate students has not only failed to be met, but at present such housing is now available to only 26 percent of the graduate students. Although the housing issue has been on our agenda for many years, the past year was one in which many groups identified it as a major issue, brought pressure on the administration to make some progress on the issue, and were rewarded near year's end with a statement from the President that some new graduate housing can be expected in the next few years. The pressure to make such a commitment came from many sources: CGSP members reported that the lack of adequate housing was beginning to be seen as a serious problem in graduate student recruitment; the supplement on graduate student concerns to the Report of the Visiting Committee on Student Affairs focused on the issue and stated that the graduate student housing issue, "if successfully addressed, would serve as the clearest indication of the Institute's commitment to strengthening the quality of graduate student life"; the housing subgroup of the FPC issued a report in which they reaffirmed "the goal of providing MIT housing for at least 40-50 percent of our graduate students"; and the GSC presented President Paul E. Gray with a petition signed by 2,416 graduate students requesting that graduate student housing be included as a priority item in the anticipated financial campaign. In April, before a meeting of the GSC, Dr. Gray indicated that preliminary planning for the development of

additional graduate student housing would soon be undertaken.

During the past year the Office of the Dean of the Graduate School (ODGS) worked closely with the GSC on a number of activities. (It is worth digressing here momentarily to note that the GSC has grown in recent years to an effective, articulate outlet for the representation of graduate student concerns. Strong leadership, an effective newsletter, and active members have made the GSC a student organization of growing importance on the MIT campus). These activities included the housing petition, a major survey of graduate students (the final results of which will be available early in the next year), and development of a statement of "Graduate Student Rights and Responsibilities."

Work on the statement of "Graduate Student Rights and Responsibilities" proceeded as a joint effort of the Academic Projects and Policies Committee of the GSC and the Subcommittee for the Review of Academic Actions of the CGSP. Those two groups met frequently throughout the past year and by year's end had nearly completed a formal document for presentation to the CGSP. It is anticipated that the completed document will be reviewed and, hopefully, endorsed by the CGSP early in the next year. The document has two objectives which are to:

- (1) define and address the roles, relationships, and expectations which currently exist between the graduate student and various units of the Institute with which he/she comes into daily contact;
- (2) identify the fundamental principles that guide these relationships.

Our experience in dealing with a broad spectrum of student and student faculty problems within the ODGS suggests that such a document will be invaluable in helping to deal with and avoid many of these problems in the future.

Through its several subcommittees the CGSP dealt with a number of special issues during the past year. Most noteworthy was the work of the Subcommittee on Academic Issues which conducted a review of how to deal with the removal of the listing of "Fields of Study" from the MIT Bulletin. After careful review of several options, the subcommittee recommended that the concept of Fields of Study be eliminated entirely and that the wording of doctoral diplomas be changed so that the awarding department or program be identified there rather than the Field of Study. This proposal was endorsed by the CGSP, and will be taken to the FPC early next year for consideration.

The CGSP reviewed a number of program changes including: reestablishment of the Naval Engineer Degree, establishment of a Master of Science degree program in Urban Studies and Planning, establishment of an interdepartmental Program in Polymer Science and Technology, and the addition of an option in Applied Biological Sciences to the Medical Engineering and Medical Physics program. These were all endorsed by the CGSP and passed on to the faculty for consideration where appropriate. The CGSP also carried out its usual academic review functions at the end of each term by reviewing grades, issuing academic warnings where appropriate, terminating the registration of several students whose performance was unsatisfactory, and recommending candidates for advanced degrees.

In order to plan more effectively for computerization of the ODGS, Professor Emeritus J. Francis Reintjes was engaged on a part-time basis for consultation. Under his guidance the Office added a second terminal for connection to the Registrar's Data Base, began successfully to use electronic mail for communication with graduate deans at other institutions, and purchased two IBM PC/AT personal computers which will initially be used for internal operations; but which will eventually be linked to the Registrar's and Admissions Office Data Bases. The Office also submitted a proposal to the Office of Information Systems to participate in a pilot program of the Administrative Information Systems Strategic Plan. That proposal, along with seven others, was selected; and the Office began active participation in that program at year's end.

The ODGS continued its special concern for the attraction and support of women and minority graduate students at MIT. Special sections of this report written by Associate Deans Jeanne E. Richard and John B. Turner address these issues. Particular note should be taken, however, of a new initiative to attract graduate students to the School of Science through a Summer Science Program for Minorities. This initiative, which is modeled after the very successful summer program at Lincoln Laboratory for students in engineering and physics, was planned during the past year and received its first students in June 1986.

On the national scene we have continued to watch with interest the progress toward Reauthorization of the Higher Education Act and the various tax reform measures. Both of these appear to be moving toward enactment at some time during the 1986 calendar year and have significant impacts on the availability of funding for graduate education and the tax status of graduate students. In April, Dean Frank E. Perkins presented testimony before the Subcommittee on Labor, Health and Human Services, and Education of the Committee on Appropriations in the United States House of Representatives concerning the FY 1987 Department of Education Budget.

Several staff members of the ODGS continued to be active in the Association of Graduate Schools in the American Association of Universities, and the Council of Graduate Schools.

Finally, it should be noted that the staff of the ODGS continued their efficient and generally thankless task of processing the thousands of pieces of paper and the hundreds of inquiries that are associated with Research and Teaching Assistant appointments, graduate fellowships and petitions. They perform these tasks in a manner that is helpful, timely, and accurate.

I and my colleagues in the Graduate School Office wish to express our thanks and appreciation to members of the CGSP for their service during this past year. Those terminating their service this year and their replacements are:

**Materials Science and Engineering**

Professor Bernhardt Wuensch to Professor Samuel Allen

**Economics**

Professor Robert Bishop to Professor Michael Piore

**Mathematics**

Professor Nesmith Ankeny to Professor Sigurdur Helgason

FRANK E. PERKINS

**WOMEN GRADUATE STUDENTS**

**Enrollment** (Tables VII, VIII, IX)

As noted in an earlier section, MIT's graduate student population continued its annual increase in the Fall of 1985. However, for the first time in recent memory the number of women graduate degree candidates remained the same at 981. Even more disappointing is the fact that the proportion of women graduate students dropped from 21 percent in the Fall of 1984 to 20 percent in the Fall of 1985. This drop reverses the modest growth in that proportion which had been experienced in each of the last several years.

The above decrease was not uniform in all Schools or departments. A decrease in the proportion of women enrolled in the School of Architecture and Planning from 41 percent to 36 percent reflects a corresponding decrease of 21 percent in the number of applicants. At the same time this corresponds to an increase of 23 percent in the number of male applicants. Interestingly enough, this is an exact reversal of the situation in the Fall of 1984!

Other Schools showed less dramatic changes in the women's enrollment/applications picture. These include a drop in the proportion of women enrolled in the Sloan School of Management from 29 percent to 27 percent (applications were down six percent), and a small decrease in number of women registered in the School of Science (279 to 274) which resulted in their proportion of the total graduate enrollment remaining the same (25 percent). However, it should be pointed out that applications from both men and women to departments in the School of Science decreased - female applicants decreased nine percent, while males decreased five percent.

Fewer women applied to the School of Engineering (down two percent), but their enrollment increased from 295 to 308 to result in the proportion of women remaining the same as last year at 13 percent.

It is troublesome to note that the number of women enrolled in graduate degree programs at MIT is not increasing as rapidly as one might anticipate. We shall be monitoring these figures closely in the future and will suggest additional recruiting initiatives where appropriate.

**Degrees Awarded to Women** (Tables X, XI, XII)

On a brighter note, we are pleased to report that the number of degrees awarded to women has increased this year. The 87 doctoral degrees earned by women represents the biggest annual total ever and is 19 percent of the total doctorates awarded. Of particular interest are the 20 doctoral degrees awarded to women in the School of Engineering. This represents almost 10 percent of the total where less than ten years ago, some of us will recall, some Engineering departments had no women doctoral degree candidates!

In other Schools we note that women earned 40 percent of the doctoral degrees in the School of Architecture and Planning, 24 percent of the doctorates in Humanities and Social Sciences, and 29

percent of the doctoral degrees in the School of Science. We can only hope that the Sloan School, which had no women doctoral candidates, was experiencing an "off year", and that there are now several women in the pipeline.

A similar story is true of Master's degrees earned by women at MIT. The 220 degrees earned represent 21 percent of the total (up from 20 percent last year) and are also an all-time high in total number.

The total of graduate degrees awarded to women in 1985-86 (307) represents 20 percent of all graduate degrees, a figure identical to the proportion of women in the graduate population.

#### Financial Aid

Financial support for graduate students is always a topic of concern. During the past year, women continued to increase their share of awards in national competitions. Specifically, 25 percent (7/28) of the Hertz Fellows at MIT were women as were 22 percent (46/201) of the National Science Foundation (NSF) Fellows. The Office of Naval Research (ONR) Fellowship program is only in its third year of existence, but 23 percent (5/21) of the ONR Fellows at MIT are women.

MIT's only fellowship program primarily for women - the Ida M. Green Fellowships - has made a total of 89 such awards in the twelve years of its existence. With the six new women recently selected for 1986-87 awards, the total will be 95. As an indication of the caliber of women selected for this program, I am proud to report that during the past year eight of these women earned their doctoral degrees. This brings the total degrees awarded to Ida Green scholars to 27 doctorates and 21 Master's degrees (including three Master of Architecture degrees and two Master of City Planning degrees). Most are now pursuing lucrative careers in academia, industry, government, with some who have started their own businesses, and a few who have gone on to earn higher degrees elsewhere. At least one woman has subsequently earned her law degree, and two are pursuing medical studies.

The few national scholarship programs designated specifically for women graduate students are also well represented at MIT. Those represented during the past year include the American Association of University Women Dissertation Fellowships, Graduate Research Program for Women sponsored by the Bell Laboratories, Xerox Special Opportunities Fellowships Program, and the IBM Fellowship Program for Women and Minorities.

At the same time women continue to be supported as Research and Teaching Assistants by their departments. An increasing number are being sponsored by industrial fellowships including Hughes Aircraft, Bell Laboratories, American Telephone and Telegraph Education Foundation, Aerospace Corporation, Digital, International Business Machines, and Shell Oil.

#### Advisory Committee for Women Students' Interests

As noted above, the voice of the graduate student body is beginning to be heard at MIT. In addition to the graduate student initiatives noted, yet another graduate student study has been under way this past year conducted by the Advisory Committee for Women Students' Interests. This survey, designed by students, faculty and staff members of the Committee, was distributed to all graduate students as part of an Institute-wide study to document the experiences of graduate students at MIT. This rather lengthy, seven-page questionnaire sought information concerning academic and professional development of graduate students while at MIT, as well as their educational experiences, including obtaining financial support, taking of general examinations, finding a research group, and receiving feedback concerning academic performance.

Another set of questions is concerned with issues of potential barriers to academic achievements such as harassment, discrimination, bias, or unequal access to the academic resources on campus.

Most of the questionnaires which have been returned have been statistically analyzed on a department-by-department basis by two-member "teams" of the Advisory Committee. As the results for each department are summarized, members of the Committee plan to talk with department heads or others within each department to discuss and point out real or potential problems. This review is not yet complete, but it is hoped that the study will be finished early in the next academic year. Eventually a report summarizing the results will be published and presented to various committees and groups at MIT including the CGSP.

Although this study was initially conceived to find out whether there were differences in male and female experiences at MIT, preliminary data indicate a striking similarity of concerns, expressed by both men and women, although there are, of course, many variances among departments. It will be important, however, to note any particular concerns expressed by women, particularly if the decrease in women applicants experienced in several departments this past year continues.

JEANNE E. RICHARD

## MINORITY GRADUATE STUDENT AFFAIRS FOR 1985-86

We had a very full and positive year at MIT in the area of minority graduate student affairs for 1985-86. The Black Graduate Student Association, under the superb leadership of Ms. Melissa Kirven, Ph.D. student in the Applied Biological Sciences Department, and Mr. Edmund Moore, a graduate student in the Materials Science and Engineering Department, helped plan and implement a wide array of activities and programs to enhance the smooth adjustment and development of minority graduate students to the Institute.

The year got off to a bang with an informative and helpful orientation program in September for new minority graduate students. First-year minority graduate students were introduced to Institute administrators and staff members whom they would more than likely interact with during the course of their stay here as graduate students; e.g., Student Financial Aid Office, Student Affairs Office, Medical Department, Campus Police, Counseling Services, Office of Minority Education, Office of the Dean of the Graduate School, etc. Advanced graduate students formed a panel during the afternoon's portion of the program and gave entering students helpful hints and advice on selecting a thesis topic and a thesis advisor, taking doctoral qualifying examinations, getting into a study group and/or research group, working with faculty members, taking advantage of the cultural and entertainment attractions in Boston, getting out of MIT with a degree, where to shop, where to get a haircut, and how to handle the stress of a new environment and attending graduate school. Before the new students arrived on campus, an energetic and creative committee of graduate students designed and printed a 56-page Minority Graduate Student Guide to give out to every minority graduate student and minority faculty member on campus.

During the course of the 1985-86 academic year minority graduate students participated in the minority graduate student recruitment program sponsored by the ODGS. Continuing minority graduate students, minority faculty, and administrators visited over 25 colleges and universities to attract talented minority graduate students to attend MIT. Students also helped organize monthly informal discussion groups with invited guest speakers; sponsored activities for Black History Month and its annual Ebony Affair Cabaret and Dance; held a reception for the Class of 1986; sponsored a Minority Awards Day Program; held monthly get-togethers; co-sponsored a fall and spring retreat at Talbot House in Vermont; and sponsored other activities to make minority students feel at home at MIT.

The numbers continue to paint a discouraging picture as far as minority applicants to MIT's Graduate School are concerned, with a 13% decline for 1985-86 compared to 1984-85. The biggest declines were in the School of Engineering (20%) and the Sloan School of Management (31%), but each school still admitted the same number of minority students as in the previous year. The total enrollment of minority graduate students for the fall term of 1985 was 139 compared to 141 the previous year. The biggest drop in enrollment came with fewer Black Americans enrolling for 1985, going from 99 students in 1984 to 89 in 1985. The downward trend is attributable to a number of factors most of which MIT cannot control; e.g., fewer minority students attending and graduating from undergraduate schools (a shrinking pool), a negative atmosphere toward equal access permeating the country; fewer fellowships and grants to encourage minority students to seek advanced training; and many students deciding to work rather than go on for a graduate degree. MIT is still very committed to recruiting talented minority graduate students and will continue to visit undergraduate schools; telephone and encourage prospective students; mail out brochures and other descriptive materials; participate in the Minority Locator Service and the National Name Exchange Program for minority students; as well as hold seminars and run feeder programs to attract bright minority students to the Institute. The problem is a massive one and it won't be solved by MIT alone; we will need help from everyone!

We are most excited about a new program that the ODGS, along with the School of Science and the Provost's Office, started this summer for minority undergraduates who are interested in developing careers in the biological and natural sciences. This new program is called the "MIT Minority Summer Science Research Program." We brought eight very bright black undergraduate students to campus in June 1986 to work in research laboratories at MIT under the tutelage and guidance of MIT faculty members, graduate students, and postdoctoral fellows. These students will gain knowledge and experience in research activities in biology, chemistry, physics, applied biological sciences, and astronomy with the hope that they will be so turned on to science during the summer that they will eventually go on for the Ph.D. degree in a science field. This country is in desperate need of more minority scientists, and this is MIT's attempt at "growing our own." We hope to expand the program to approximately 30 students for the summer of 1987. We hope that this program, along with initiatives from other universities, will begin to help turn around the declining number of minority scientists in the United States.

JOHN B. TURNER

TABLE I

For simple comparison with data for 1984-85, the following statistical information for 1985-86 is presented in the same format. Numbers in parenthesis indicate the change from 1984-85 to 1985-86.

## REGULAR GRADUATE STUDENT ENROLLMENT - FALL TERM 1985

	Foreign <sup>(1)</sup>	Women <sup>(2)</sup>	Minority <sup>(3)</sup>	Total	Non-Resident <sup>(4)</sup>
School of Architecture and Planning	171 (+ 54)	159 (-20)	20 (- 6)	441 (+ 2)	41 (- 7)
School of Engineering	880 (+108)	308 (+13)	62 (+ 4)	2367 (+95)	8 (- 1)
School of Humanities and Social Science	117 (+ 27)	118 (+ 9)	18 (+ 5)	409 (+10)	64 (- 6)
Sloan School of Management	165 (- 4)	110 (- 4)	17 (- 1)	561 (+39)	9 (NC)
School of Science	319 (+ 20)	274 (- 5)	22 (- 4)	1101 (+ 6)	18 (NC)
Health Science & Technology	6 (+ 4)	10 (+ 7)	0	32 (+ 9)	0
Health Policy & Management	0	2 (NC)	0	9 (+ 2)	0
<b>TOTAL</b>	<b>1658 (+209)</b>	<b>981 (NC)</b>	<b>139 (- 2)</b>	<b>4920 (+163)</b>	<b>140 (-14)</b>

(1) Includes Canadians

(2) See also Table IX

(3) Includes Black Americans, Puerto Ricans, Mexican Americans and American Indians

(4) Included in Totals

TABLE II  
GRADUATE DEGREES AWARDED - 1985-86

Advanced Degrees Conferred	M.C.P., M.Arch.	S.M.	Engineer	Sc.D.	Ph.D.	Total
September 1985	3 (-1)	186 (+54)	7 (-6)	6 (+1)	96 (+2)	300 (+45)
Woods Hole			0 (N.C.)	1 (+1)	1 (-3)	
February 1986	15 (+1)	189 (-48)	16 (+8)	14 (+3)	132 (-3)	373 (-35)
Woods Hole			0 (N.C.)	1 (+1)	6 (+2)	
June 1986	61 (+12)	605 (-11)	31 (-4)	28 (+1)	164 (+2)	895 (+1)
Woods Hole			0 (N.C.)	3 (+3)	3 (-2)	
Total	79 (+13)	980 (-8)	54 (-2)	53 (+10)	402 (-2)	1568 (+11)

Numbers in parentheses indicate change from 1984-85

TABLE III

## DOCTORAL DEGREES AWARDED EACH YEAR BY SCHOOL AND CITIZENSHIP

Each number is the total of the doctoral degrees awarded in September, February and June of the academic year indicated. The numbers in parentheses are the number of degrees awarded divided by the corresponding regular graduate student enrollment (5th week count).

Academic Year		Arch.	Eng'g.	Hum. and Soc. Sci.	Sloan	Science	HST	Total
1975-76	Citizen	1 (.005)	83 (.073)	49 (.232)	12 (.055)	126 (.162)		271 (.106)
	Foreign	<u>1 (.019)</u>	<u>67 (.114)</u>	<u>7 (.119)</u>	<u>2 (.017)</u>	<u>42 (.180)</u>		<u>119 (.113)</u>
		2	150	56	14	168		390
1976-77	Citizen	6 (.026)	79 (.068)	33 (.155)	2 (.007)	125 (.156)		245 (.090)
	Foreign	<u>4 (.071)</u>	<u>64 (.106)</u>	<u>19 (.264)</u>	<u>1 (.010)</u>	<u>46 (.199)</u>		<u>134 (.126)</u>
		10	143	52	3	171		379
1977-78	Citizen	5 (.023)	111 (.096)	50 (.240)	8 (.029)	119 (.146)		293 (.110)
	Foreign	<u>3 (.039)</u>	<u>66 (.103)</u>	<u>13 (.169)</u>	<u>15 (.139)</u>	<u>35 (.141)</u>		<u>132 (.115)</u>
		8	177	63	23	154		425
1978-79	Citizen	10 (.041)	80 (.066)	35 (.164)	10 (.035)	126 (.151)		261 (.093)
	Foreign	<u>3 (.033)</u>	<u>64 (.101)</u>	<u>11 (.130)</u>	<u>9 (.088)</u>	<u>33 (.142)</u>		<u>120 (.105)</u>
		13	144	46	19	159		381
1979-80	Citizen	8 (.031)	96 (.074)	40 (.156)	5 (.017)	127 (.153)		276 (.094)
	Foreign	<u>3 (.034)</u>	<u>66 (.096)</u>	<u>11 (.109)</u>	<u>3 (.029)</u>	<u>28 (.115)</u>		<u>111 (.091)</u>
		11	162	51	8	155		387
1980-81	Citizen	12 (.044)	88 (.065)	40 (.178)	7 (.022)	118 (.138)		265 (.088)
	Foreign	<u>7 (.078)</u>	<u>75 (.103)</u>	<u>12 (.153)</u>	<u>2 (.020)</u>	<u>35 (.130)</u>		<u>131 (.104)</u>
		19	163	52	9	153		396
1981-82	Citizen	7 (.023)	94 (.066)	35 (.128)	4 (.012)	124 (.148)		264 (.083)
	Foreign	<u>2 (.017)</u>	<u>75 (.104)</u>	<u>21 (.223)</u>	<u>6 (.050)</u>	<u>35 (.123)</u>		<u>139 (.103)</u>
		9	169	56	10	159		403
1982-83	Citizen	6 (.026)	93 (.070)	43 (.189)	11 (.031)	126 (.160)	1 (.100)	280 (.096)
	Foreign	<u>4 (.027)</u>	<u>78 (.102)</u>	<u>14 (.150)</u>	<u>2 (.016)</u>	<u>52 (.184)</u>	<u>2 (.222)</u>	<u>152 (.107)</u>
		10	171	57	13	178	3	432
1983-84	Citizen	9 (.035)	92 (.065)	41 (.182)	12 (.035)	115 (.150)	3 (.130)	272 (.089)
	Foreign	<u>5 (.040)</u>	<u>76 (.098)</u>	<u>16 (.168)</u>	<u>9 (.059)</u>	<u>37 (.128)</u>	<u>0</u>	<u>143 (.099)</u>
		14	168	57	21	152	3	415
1984-85	Citizen	10 (.031)	111 (.074)	32 (.104)	7 (.019)	128 (.161)	3 (.142)	291 (.088)
	Foreign	<u>3 (.026)</u>	<u>76 (.098)</u>	<u>15 (.167)</u>	<u>11 (.065)</u>	<u>50 (.167)</u>	<u>1 (.500)</u>	<u>156 (.108)</u>
		13	187	47	18	178	4	447
1985-86	Citizen	7 (.026)	119 (.080)	46 (.157)	4 (.010)	122 (.156)	3 (.115)	301 (.092)
	Foreign	<u>3 (.017)</u>	<u>89 (.101)</u>	<u>12 (.102)</u>	<u>5 (.030)</u>	<u>46 (.144)</u>	<u>1 (.166)</u>	<u>156 (.094)</u>
		10	208	58	9	168	4	457



TABLE IV  
A "SNAPSHOT" OF GRADUATE STUDENT SUPPORT "FULL AWARDS"

FALL TERM 1985

The following sources provided at least full tuition support for graduate students during the Fall Term 1985. Total regular graduate student enrollment, not including Non-Residents, was 4,780.

	<u>Numbers of Students</u>	<u>Percent of Total Enrollment</u>	<u>Change from 1984-85</u>
FELLOWSHIPS & TRAINEESHIPS AWARDED BY MIT			
NIH and NIMH Traineeships	77		-17
HEW Graduate and Professional Opportunities Program Fellowships	13		+ 1
MIT Endowed and Other Fund Fellowships	190		+11
Industrial and Foundation Fellowships	<u>188</u>		<u>+ 6</u>
	468	9.7%	+ 1
FELLOWSHIPS AWARDED BY SPONSORS TO MIT STUDENTS			
NSF Graduate Fellowships	183		+13
Hertz Fellowships	31		- 2
ONR Fellowships	<u>21</u>		<u>+ 8</u>
	235	4.9%	+15
STUDENT ASSISTANTSHIPS			
Research Assistants	1535		-36
Teaching Assistants	404		+14
Instructor G	<u>5</u>		<u>NC</u>
	1944	40.6%	-52
SPONSORED STUDENTS			
Many students receive support from employers and sponsors. The following reflect accounts billing for tuition to employers and sponsors who presumably provide stipends to students by private arrangement.			
U.S. Government	127		+ 7
Foreign Countries and International Programs	157		+ 3
Industry and Foundation (U.S.)	<u>143</u>		<u>+52</u>
	427	8.9%	+62
SUMMARY BY SOURCES - FULL AWARDS			
Federal Fellowships & Traineeships	294	6.1%	+ 5
Graduate Student Staff	1944	40.6%	-52
Industrial and Foundation Awards	219	4.5%	+ 4
MIT Endowed and Budgeted Funds	190	3.9%	+11
Students Sponsored by External Sources	<u>427</u>	<u>8.9%</u>	<u>+62</u>
	3074	64.3%	+30

TABLE V

DISTRIBUTION OF FUNDING FOR GRADUATE STUDENT TUITION AND LIVING EXPENSES  
FALL TERM 1985

Estimates of Required Funding

Tuition	\$25,957.157
Stipend (\$900/mo. for 4½ months)	18,802,638
Total Estimated Required Funding	<u>\$44,759,795</u>

Identified Support by Category

Research Assistantships	16,406,034
Teaching Assistantships	4,581,416
Federal Fellowships and Traineeships	2,871,524
General and Endowed Support (departmentally controlled)	2,000,213
General and Endowed Support (Graduate School Office controlled)	415,774
Outside Sources Administered by Departments	1,917,324
Outside Sources Administered by Graduate School Office	201,655
Outside Sources, Direct Billing to Sponsor by Institute, Tuition only	2,243,125
Total Identified Support	31,404,322
Loans	4,627,624

TABLE VI

## TRENDS IN GRADUATE STUDENT SUPPORT

(\$000's)

Academic Year	Fellowships Traineeships Scholarships*	Staff Tuition ** Awards (TA & IG)	Staff Salaries (RA & TA)	<u>Loans</u>	
				<u>MIT Only</u>	<u>Including Outside Agencies</u>
1970-71	5,396 (.655)	1,182 (.143)	6,850 (.831)	483 (.059)	672 (.082)
1971-72	5,076 (.589)	1,294 (.150)	7,086 (.823)	696 (.080)	827 (.096)
1972-73	4,687 (.486)	1,432 (.150)	7,991 (.828)	754 (.078)	916 (.095)
1973-74	3,930 (.378)	1,453 (.140)	8,781 (.844)	852 (.082)	1,014 (.097)
1974-75	3,693 (.318)	1,738 (.150)	9,760 (.840)	1,075 (.093)	1,293 (.111)
1975-76	3,447 (.259)	1,878 (.141)	10,878 (.816)	1,141 (.086)	1,407 (.106)
1976-77	3,454 (.229)	2,065 (.137)	11,654 (.722)	1,419 (.094)	2,013 (.133)
1977-78	3,418 (.205)	1,978 (.118)	12,479 (.750)	1,391 (.084)	2,201 (.132)
1978-79	3,667 (.198)	2,355 (.127)	15,251 (.823)	962 (.052)	2,387 (.129)
1979-80	3,733 (.172)	3,079 (.142)	16,610 (.766)	976 (.045)	3,575 (.165)
1980-81	3,970 (.149)	2,821 (.106)	18,650 (.702)	434 (.016)	4,434 (.167)
1981-82	4,194 (.128)	3,362 (.102)	21,258 (.648)	662 (.020)	5,412 (.165)
1982-83	5,142 (.136)	4,044 (.107)	21,993 (.581)	1,078 (.028)	4,791 (.126)
1983-84	5,561 (.130)	19,094 (.445)	12,671 (.295)	1,602 (.037)	4,576 (.106)
1984-85	6,516 (.137)	21,541 (.454)	14,131 (.298)	1,821 (.038)	5,135 (.108)
1985-86	7,249 (.138)	25,325 (.482)	16,237 (.309)	1,600 (.034)	4,947 (.094)

\*Administered by the Office of the Dean of the Graduate School

\*\*Beginning with the academic year 1983-84, tuition awarded to Research Assistants is included under "Staff Tuition Awards".

To "normalize" these data, the total dollar values have been divided by the product (total regular graduate students registered for the fall term)(tuition for the 9-month academic year).

TABLE VII  
WOMEN GRADUATE STUDENT ENROLLMENT  
Comparison of Fall Term Enrollments - 1984 & 1985

	<u>Number of Women</u>		<u>% of Women in Total Enrollment</u>	
	<u>1984</u>	<u>1985</u>	<u>1984</u>	<u>1985</u>
<u>School of Architecture &amp; Planning</u>				
Architecture IV	87	79	35.5%	32%
Urban Studies & Planning XI	<u>92</u>	<u>80</u>	<u>47%</u>	<u>42%</u>
	179	159	41%	36%
<u>School of Engineering</u>				
Aeronautics & Astronautics XVI	21	20	10%	9%
Chemical Engineering X	34	34	16%	15%
Civil Engineering I	29	30	13%	12%
Elec. Engineering & Comp. Science VI, A, W	104	107	16%	16%
Materials Science III, III-B, III-W	42	52	17%	19%
Mechanical Engineering II, II-T, II-W	40	39	9%	9%
Nuclear Engineering XXII	17	17	10%	11%
Ocean Engineering XIII, XIII-A, XIII-B	6	9	4%	7%
XIII-W	<u>2</u>	<u>0</u>	<u>18%</u>	<u>0%</u>
	295	308	13%	13%
<u>School of Humanities &amp; Social Sciences</u>				
Economics XIV	14	16	11%	12%
Linguistics & Philosophy XXIV	30	31	48%	48%
Political Science XVII	53	58	30%	33%
Psychology IX	<u>12</u>	<u>13</u>	<u>35%</u>	<u>35%</u>
	109	118	27%	29%
<u>Sloan School of Management</u>				
Management XV	91*	83	24%*	20%
XV-P	13	14	16.6%	19%
XV-A (Fellows)	6	9	10.5%	17%
XV-B (Operations Research)	<u>4</u>	<u>4</u>	<u>26.6%</u>	<u>25%</u>
	114	110	22%	20%
<u>School of Science</u>				
*** Applied Biological Sciences XX	52	49	44%	43%
Biology VII	48	44	33.3%	31%
VII-W	12	12	60%	70.5%
Chemistry V	57	61	27.5%	27%
** Earth, Atmospheric, & Planetary Science XII	22	26	19%	22%
XII-W	23	27	38%	39%
Mathematics XVIII	26	17	20%	14%
Physics VIII	<u>39</u>	<u>38</u>	<u>13%</u>	<u>13%</u>
	279	274	25%	25%
HST	3	10	13%	31%
HPM	2	2	28.5%	22%
TOTALS	981	981	21%	20%

\*Figures include totals for XV & XV-P

\*\*Figures include former Crse XIX & XIX-W

\*\*\*Formerly Nutrition & Food Science

**TABLE VIII**  
**Women Graduate Student Enrollment**  
**(% of total 1974-85)**

<u>Fall Term</u>	<u>New</u>		<u>% of Women</u>	<u>Continuing</u>		<u>% of Women</u>	<u>Total</u>		<u>% of Women</u>
	<u>Women</u>	<u>Total</u>		<u>Women</u>	<u>Total</u>		<u>Women</u>	<u>Total</u>	
1974	140	1,061	13%	265	2,407	11%	405	3,468	12%
1975	175	1,113	16%	312	2,490	12.5%	487	3,603	13.5%
1976	185	1,220	15%	361	2,554	14%	546	3,774	14%
1977	192	1,184	16%	367	2,640	14%	559	3,824	14.6%
1978	218	1,259	17%	388	2,685	14%	606	3,944	15.4%
1979	193	1,202	16%	491	2,944	16.6%	684	4,146	16.4%
1980	254	1,308	19%	525	3,076	17%	779	4,384	18%
1981	243	1,272	19%	585	3,269	18%	828	4,541	18%
1982	267	1,306	20%	589	3,183	19%	856	4,489	19%
1983	258	1,302	20%	656	3,329	20%	914	4,631	20%
1984	265	1,290	20.5%	716	3,467	21%	981	4,757	21%
1985	255	1,375	18.5%	726	3,546	20%	981	4,920	20%

TABLE IX  
COMPARISON OF ADMISSIONS STATISTICS FOR GRADUATE WOMEN AND GRADUATE MEN  
Number of Applicants 1984/Number of Applicants 1985

	<u>Women</u>	<u>Men</u>
School of Architecture & Planning	309/243 (-21%)*	393/482 (+23%)*
School of Engineering	376/369 (-2%)	2926/3038 (+4%)
School of Humanities & Social Science	199/250 (+25%)	496/504 (+2%)
Sloan School of Management	331/350 (+6%)	1408/1446 (+3%)
School of Science	432/391 (-9%)	1276/1216 (-5%)
HST (not available 1985)		
TOTALS	1647/1603 (-3%)	6499/6686 (+3%)

\*Numbers in parentheses indicate the % change in number of applicants from 1984 to 1985

TABLE X

Comparison of Women Enrolled with Women Degree Recipients, 1985-86

	% of Women Enrolled		% of Degrees awarded to Women			
			Master's	Doctoral		
Architecture & Planning	36% (41%)	(159/441)	40% (42%)	(62/156)	40% (54%)	(4/10)
Engineering	13% (13%)	(308/2367)	16% (12%)	(95/601)	9.6% (8%)	(20/208)
Humanities & Social Science	29% (27%)	(118/409)	41.6% (44%)	(5/12)	24% (30%)	(14/58)
Sloan School of Management	20% (22%)	(110/561)	19% (23%)	(49/252)	0% (11%)	(0/9)
Science	25% (25%)	(274/1101)	24% (19%)	(9/38)	28.5% (23%)	(48/168)
HST	31% (13%)	(10/32)	none		25% (25%)	(1/4)
<u>TOTAL</u>	20% (21%)	(981/4920)	21% (19%)	(220/1059)	19% (17%)	(87/457)
ALL DEGREES				20% (18%)	(307/1516)	

(%) = 1984-85 figures

TABLE XI

Degrees Awarded to Women by School

	<u>1976-77</u>	<u>1977-78</u>	<u>1978-79</u>	<u>1979-80</u>	<u>1980-81</u>	<u>1981-82</u>	<u>1982-83</u>	<u>1983-84</u>	<u>1984-85</u>	<u>1985-86</u>
<u>Architecture &amp; Planning</u>										
Master's*	34	23	33	41	48	51	48	50	48	62
Doctor's	2	4	3	5	6	2	6	2	7	4
<u>Engineering</u>										
Master's	28	42	50	51	52	84	72	81	77	95
Doctor's	8	4	4	7	14	10	14	7	15	20
<u>Humanities &amp; Social Sciences</u>										
Master's	5	4	3	3	3	5	5	2	7	5
Doctor's	10	12	4	12	14	10	14	20	14	14
<u>Sloan (XV, XV-A, XV-P)</u>										
Master's	46	40	45	34	49	47	47	54	57	48
Doctor's	0	2	0	1	1	0	3	4	2	0
<u>Science</u>										
Master's	32	25	14	27	21	25	25	23	6	9
Doctor's	28	23	18	20	26	23	29	25	37	47
<u>Operations Research (XV-B)</u>										
Master's	0	1	0	0	1	2	1	1	1	1
Doctor's	0	1	0	0	2	0	1	0	0	0
<u>WHOI</u>										
Doctor's	1(VII-W) 1(XII-W)	1(VII-W) 0 1(XII-W)	0 1(XII-W)	1(VII-W)	2(XII-W) 1(XIX-W)	3(XII-W) 1(XIX-W)	2(XII-W) 2(XII-W)	1(VII-W) 1(VII-W)	2(XII-W) 0	0
<u>HST</u>										
Doctor's	-	-	-	-	-	-	1	0	1	1
<u>TOTALS</u>										
Master's	145	135	145	156	184	214	198	211	196	220
Doctor's	50	48	29	47	65	49	71	61	78	87

\*M.Arch., MCP, SM



TABLE XII  
Comparison, in Numbers, of Degrees awarded to Men and Women

<u>1975-76 to 1985-86</u>												
	<u>Master's</u>			<u>Doctor's</u>			<u>Engineer's</u>			<u>All</u>		
	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>
1975-76	93	862	11%	33	390	8%	2	94	2%	126*	1252*	10%*
										128	1346	9.5%
1976-77	145	971	15%	50	379	13.2%	2	91	2%	195*	1350*	14.5%*
										197	1441	13.7%
1977-78	135	934	14%	48	425	11%	5	108	5%	183*	1359*	13.4%*
										188	1467	12.7%
1978-79	145	968	15%	29	387	7%	2	65	3%	174*	1355*	12.8%*
										176	1420	12.3%
1979-80	156	984	16%	47	386	12%	3	77	4%	203*	1370*	14.8%*
										206	1447	14%
1980-81	184	1018	18%	65	396	16%	3	72	4%	249*	1414*	17.6%*
										252	1486	16.9%
1981-82	214	1118	19%	49	403	12%	5	64	8%	263*	1521*	17.3%*
										268	1585	16.9%
1982-83	198	1124	17.5%	71	432	16.5%	0	67	0%	269*	1556*	17%*
										269	1623	16.5%
1983-84	211	1084	19%	61	415	15%	9	73	12%	272*	1499*	18%*
										281	1572	18%
1984-85	196	1055	18.5%	78	446	17.5%	3	56	5%	274*	1501*	18%*
										277	1557	18%
1985-86	220	1059	21%	87	457	19%	3	54	5%	307*	1516*	20%
										310	1570	20%

\*Without Engineer's Degrees

TABLE XIII  
Minority Graduate Student Enrollment  
Fall 1985

	BA	PR	MA	AI	Total Minority Grad Students	Total All Grad Students	Minority % of Total
<u>Architecture &amp; Planning</u>							
Architecture	6	1	0	0	7	250	2.8%
Urban Studies & Planning	6	2	3	2	13	191	6.8%
School Totals	<u>12</u>	<u>3</u>	<u>3</u>	<u>2</u>	<u>20</u>	<u>441</u>	<u>4.5%</u>
<u>Engineering</u>							
Aeronautics & Astronautics	5	0	0	0	5	222	2.2%
Chemical Engineering	3	0	2	0	5	222	2.2%
Civil Engineering	1	0	1	0	2	245	.8%
Electrical Engineering	20	2	7	1	30	661	4.5%
Materials Science	3	2	1	0	6	279	2.2%
Mechanical Engineering	5	2	2	1	10	445	2.2%
Nuclear Engineering	1	0	3	0	4	150	2.7%
Ocean Engineering	0	0	0	0	0	143	0
School Totals	<u>38</u>	<u>6</u>	<u>16</u>	<u>2</u>	<u>62</u>	<u>2367</u>	<u>2.6%</u>
<u>Sloan School of Management</u>							
Two-Year's Master's Prog.	11	1	1	1	14	425	3.3%
Sloan Fellows	1	0	0	0	1	54	1.9%
Operations Research	1	0	0	0	1	16	6.3%
Ph.D. Program	0	0	0	1	1	66	1.5%
School Totals	<u>13</u>	<u>1</u>	<u>1</u>	<u>2</u>	<u>17</u>	<u>561</u>	<u>3.0%</u>
<u>Humanities &amp; Social Science</u>							
Economics	3	1	2	1	7	131	5.3%
Linguistics & Philosophy	1	1	0	0	2	65	3.1%
Political Science	4	1	2	1	8	176	4.5%
Psychology	0	0	1	0	1	37	2.7%
School Totals	<u>8</u>	<u>3</u>	<u>5</u>	<u>2</u>	<u>18</u>	<u>409</u>	<u>4.4%</u>
<u>Science</u>							
Applied Biological Sciences	4	0	0	0	4	115	3.5%
Biology	3	0	0	0	3	158	1.9%
Chemistry	0	0	0	1	1	224	.4%
Earth, Atmos., Planetary	0	0	0	0	0	188	0
Mathematics	0	0	1	0	1	124	.8%
Physics	<u>11</u>	<u>1</u>	<u>1</u>	<u>0</u>	<u>13</u>	<u>292</u>	<u>4.5%</u>
School Totals	<u>18</u>	<u>1</u>	<u>2</u>	<u>1</u>	<u>22</u>	<u>1101</u>	<u>2.0%</u>
Health Policy & Management	0	0	0	0	0	9	0
Health Sci. & Technology	0	0	0	0	0	32	0
Grand Total	89	14	27	9	139	4920	2.8%

TABLE XIV  
Trends in Minority Graduate Enrollment at MIT

<u>School</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Architecture & Planning	50	59	44	46	45	57	41	31	35	26	20
Engineering	38	44	40	44	47	58	55	55	62	58	62
Management	9	17	20	13	9	16	10	12	7	18	17
Humanities & Social Sciences	30	27	21	16	9	15	9	12	14	13	18
Science	28	31	32	28	34	25	25	28	27	26	22
Minority Total	155	178	157	147	144	171	140	139	145	141	139
All Graduate Total	3603	3744	3824	3944	4146	4327	4435	4349	4631	4603	4920

Black Graduate Enrollment

<u>School</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Architecture & Planning	30	23	25	19	12
Engineering	35	34	41	41	38
Management	10	12	5	14	13
Humanities & Social Sciences	5	5	8	5	8
Science	17	18	20	20	18
Total Black Enrollment	97	93	99	99	89

TABLE XV  
Minority Applicants Received, Admitted, and Enrolled  
1984-85 vs 1985-86

	<u>Rec'd</u>	<u>1984-85</u> <u>Ad</u>	<u>Enrolled</u>	<u>Rec'd</u>	<u>1985-86</u> <u>Ad</u>	<u>Enrolled</u>
<u>Architecture &amp; Planning</u>						
Architecture	9	5	3	19	3	2
Urban Studies & Planning	<u>11</u>	<u>8</u>	<u>6</u>	<u>7</u>	<u>5</u>	<u>4</u>
	20	13	9	26	8	6
<u>Engineering</u>						
Aeronautics & Astronautics	3	2	1	2	2	1
Chemical Engineering	6	1	1	5	1	1
Civil Engineering	3	1	0	1	1	1
Electrical Engineering	37	10	9	28	9	7
Materials Science	5	3	3	3	1	1
Mechanical Engineering	4	2	0	2	5	2
Nuclear Engineering	3	2	2	2	2	1
Ocean Engineering	0	0	0	0	0	0
	<u>61</u>	<u>21</u>	<u>16</u>	<u>49</u>	<u>21</u>	<u>14</u>
<u>Sloan School of Management</u>	45	17	10	31	17	7
<u>Humanities &amp; Social Sciences</u>						
Economics	7	3	1	5	1	1
Linguistics & Philosophy	0	0	0	3	2	1
Political Science	4	3	3	5	4	2
Psychology	<u>2</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>0</u>	<u>0</u>
	13	7	5	14	7	4
<u>Science</u>						
Applied Biological Sciences	2	0	0	2	0	0
Biology	1	1	0	3	1	0
Chemistry	3	0	0	4	1	1
Earth, Atmos, & Planetary	0	0	0	1	0	0
Mathematics	2	1	1	0	0	0
Physics	<u>9</u>	<u>4</u>	<u>1</u>	<u>6</u>	<u>3</u>	<u>2</u>
	17	6	2	16	5	3
Grand Total	156	64	42	136	58	34

TABLE XVI

Minority Graduate Degree Recipients  
(September, February, June Degree Lists)

	<u>Black American</u>	<u>Mexican American</u>	<u>Puerto Rican</u>	<u>American Indian</u>	<u>Total</u>
Master's Degree	19	7	2	0	28
Engineer's Degree	0	0	0	0	0
Doctor's Degree	3	3	1	0	35
Total	<u>22</u>	<u>10</u>	<u>3</u>	<u>0</u>	<u>35</u>

<u>Graduation Date</u>	<u>Master's Degree</u>				<u>Engineer's Degree</u>				<u>Doctor's Degree</u>			
	BA	MA	PR	AI	BA	MA	PR	AI	BA	MA	PR	AI
September	5	1	1	0	0	0	0	0	1	0	0	0
February	3	2	0	0	0	0	0	0	0	1	1	0
June	<u>11</u>	<u>4</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>2</u>	<u>2</u>	<u>0</u>	<u>0</u>
Total	<u>19</u>	<u>7</u>	<u>2</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>3</u>	<u>3</u>	<u>1</u>	<u>0</u>

<u>School</u>	<u>Master's</u>	<u>Engineer's</u>	<u>Doctor's</u>	<u>Total</u>
Architecture & Planning	6	0	0	6
Engineering	15	0	3	18
Humanities & Social Sciences	1	0	1	2
Science	0	0	3	3
Sloan School of Management	6	0	0	6

The Lowell Institute School (LIS) was established at MIT in 1903 to provide evening instruction in technical subjects for residents of the Boston area. Today the School continues this tradition by offering subjects in the areas of modern technology which are not readily available at other evening institutions. Entry-level courses require an adequate high school preparation, and the more advanced instruction is geared to the practicing technician who has an Associate degree or equivalent experience.

The programs of study range from single subjects designed to broaden job skill levels to comprehensive study of new technological areas in preparation for employment in a new field. There is a strong emphasis on practical aspects and development of careful experimental technique combined with sufficient theory to provide an adequate foundation of understanding. Certificates are awarded to those who satisfactorily complete a course. In addition, students who complete a program of courses may earn a Certificate in Drafting Technology or a Certificate in Electronics Technology.

During 1985-86, LIS offered 35 different courses. The fields of instruction included analog and digital electronics including microprocessors through advanced applications; computer programming in BASIC and C; mechanical, electrical, and architectural drafting; geometric dimensioning and tolerancing; mechanical computer aided design; printed circuit board design; blueprint reading; machine tools; metal joining; first level management; building maintenance; and housebuilding. In addition, refresher courses were offered in mathematics to support both the drafting and electronics curricula. New courses were introduced in mechanics, thermal systems, advanced geometric dimensioning and tolerancing, and architectural design.

LIS continued to offer courses in the intensive daytime format for individuals working in industry. A course in welding technology was conducted in-house at Babco Industries in Danvers, MA for its employees.

LIS admitted a total of 1,043 students to its courses in 1985-86. Of those enrolled, 77 percent successfully completed the certificate requirements. Among those who completed courses were 56 MIT employees. Eight students earned the Certificate in Drafting Technology, and eight students the Certificate in Electronics Technology.

The past academic year has seen LIS expand its program of unique evening courses which no other Boston area school can match. The high percentage of students who successfully complete their courses indicates that both the subjects offered and the level of instruction are well matched to their needs.

BRUCE D. WEDLOCK

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## Summer Session

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### Special Programs

The Summer Session Office administers an extensive series of one- and two-week special programs for professional men and women who wish to keep pace with developments in their fields. This activity has prospered each summer since its initiation in 1950. Current information on subjects and registrations are as follows:

Summer 1984 - 1,826 registrations in 67 special programs

Summer 1985 - 1,754 registrations in 63 special programs

Foreign citizens comprise approximately 11 percent of this registration.

### Regular Subjects

Graduate students comprise 80 percent of the student body in summer. The 1984 registration of 9,626 students was an increase from the 2,616 in 1983.

FREDERICK J. MC GARRY

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## Upward Bound Program

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The MIT/Wellesley Upward Bound Program is a coeducational, multiracial educational program for Cambridge high school youth. Now in its nineteenth year, the Program services 70 academically promising young men and women from disadvantaged backgrounds. The goal of the Program is to motivate these youths to attend college, and to provide them with the necessary skills needed to succeed in college. To a large extent, the Program is influenced by the research done in the 1930's and '40's by social psychologist Kurt Lewin and his associates. The Program has met with good success, operating on the assumption that ego growth and academic performance are closely related. A developing ego needs to experience success in a warm and personal structured environment to develop strongly, in both a personal and social sense. This development can be brought about through intervention outside of the family and school.

Upward Bound represents such an intervention. It has been established that the effects of failure can be reversed by presenting a young person with real success, and that further success leads to an increase in the student's level of aspiration. The program staff are often the first to see real academic promise in the youngsters. The staff, together with teachers and fellow students, play a crucial role, because what students think they can do is dependent on what others think they can do. The students' perceptions of their abilities, and therefore what they will try to accomplish, are thus to a large extent determined by the staff.

### SUMMER PROGRAM

The summer program, conducted in residence on the Wellesley College campus for six weeks, is designed to provide the student with an intense academic and social experience. Classes are team-taught by experienced high school teachers, students from Wellesley College and MIT, undergraduate and graduate students from local colleges and universities, and Upward Bound alumni now attending college. Upward Bound students carry three classes, each of which meets for an average of five and one half hours per week, with three additional hours of supervised study, during the six-week summer program. Additionally, students are assigned to tutorials whenever the need arises. Each student is required to take a mathematics and an English course and one science elective. Science courses include biology, physics, human physiology, computers, and chemistry. The mathematics program includes an enrichment section for students who have done poorly in basic arithmetic, algebra I, II, geometry, trigonometry, and pre-calculus and calculus courses for students who will be attending college in the fall.

### THE ACADEMIC YEAR

The academic year program, while somewhat less intense due to its after school format, is equally important. Building on the motivation and enthusiasm developed over the summer, the academic year program is designed to help the student cope with the myriad of academic, social, and family problems that confront him or her in Cambridge. To achieve this, the following programs, staffed primarily by MIT or Wellesley College undergraduates, have been developed and implemented:

Study Skills. The MIT Upward Bound office is open for study four days a week: Mondays, Tuesdays and Wednesdays from 3 to 6 P.M. and Thursdays from 3 to 8 P.M. Tutors are on duty to provide homework supervision for both individuals and small groups. Tutors are typically MIT or Wellesley College undergraduates who meet regularly with core staff to discuss students' progress and/or difficulties.

Tutoring. Whenever requested or needed, tutors are assigned to individual students. These pairings meet on a regular basis at a specified day and time until it is mutually agreed that the individual tutorials are no longer necessary (usually indicated by improvement of grades). Organization and time management are stressed, as well as effective negotiation techniques.

### COLLEGE REPORT, CLASS OF 1986

Graduating seniors have been placed in colleges as follows: Amherst College (2), Boston College (2), Emerson College, Hampton University, Lesley College, Mount Ida College, Northeastern University, Roger Williams College, Spelman College, Suffolk University, Syracuse University, University of Massachusetts at Amherst (4), University of Massachusetts at Boston and Williams College.

We continually strive to increase participation by MIT and Wellesley College undergraduates through our continued involvement in the Wellesley College Teacher Certification Program and various outreach efforts.

RONALD S. CRICHLAW



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## ROTC Programs

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### AIR FORCE ROTC

The Air Force Reserve Officer Training Corps (AFROTC) program at MIT continues to provide challenging and comprehensive leadership and academic training for students attending MIT, Harvard, Tufts and Wellesley. Year-end enrollment in AFROTC as of June 1986 was as follows:

	Freshmen	Sophomores	Juniors	Seniors	Total
MIT	40	33	43	38	154
Harvard	12	1	7	3	23
Tufts	6	8	8	6	28
Wellesley	1	2	0	1	4
Total	59	44	58	48	209

Besides providing opportunities for the development of leadership skills, the AFROTC program provided MIT cadets with over \$1.5 million for tuition. Cadets from the other schools received tuition payments exceeding \$.7 million. Additional payments for textbooks and subsistence exceeded \$.2 million.

Concluding academic year 1985-86, thirty-nine senior cadets received commissions as second lieutenants in the Air Force. Twenty-eight of these were MIT graduates from engineering curriculums, including three who will go on to pilot training and one who will train to become a navigator.

As in the past, several special cadet activities highlighted this year's training for AFROTC students. These events included the Annual Tri-Service Awards Banquet, the Military Ball, Field Day, the Annual Tri-Service Pass-in-Review Parade. The year concluded with the traditional commissioning on board the U.S.S. Constitution.

Colonel Emmanuel J. Scivoletto, AFROTC Detachment Commander, completed his second year of dedicated service at MIT and will continue to provide outstanding leadership to his 10-member staff for another academic year.

CAPTAIN RANDY L. BLISS, USAF

### ARMY ROTC

The 1985-86 Academic Year was extremely productive for the Army Reserve Officers' Training Corps (ROTC) Program. Overall enrollment throughout the year increased beyond any level of the past five years. Over the academic year a total of 104 students participated in our program. At year's end, 92 of those students were still enrolled, an increase of 14 cadets over last year. This increase in enrollment can be attributed to three main factors: first, we are seeing a resurgence of patriotic values within American high school youths, and they are in turn seeing military service as a worthwhile endeavor; secondly, as sources of college financial aid become more scarce, our full-tuition scholarship becomes considerable more attractive; and thirdly, we have stepped up our recruiting efforts as they pertain to the incoming freshman class of all four schools. The third factor is probably the most important element of our success. We have found that there are a lot of incoming freshmen who have a basic interest in military service, yet, in past years they were not being made aware prior to college matriculation that when attending MIT, Harvard, Tufts or Wellesley, they could participate in our officer training program. Our mass mailing campaigns explain in detail what we have to offer and exactly how to go about enrolling in our program when they arrive. Responses to the mailings are impressive.

A breakout of year end enrollment by year and institution is shown below:

	Freshmen	Sophomores	Juniors	Seniors	Total
MIT	13	9	19	10	51
Harvard	3	3	6	6	18
Tufts	4	2	1	2	9
Wellesley	5	5	1	3	14
Total	25	19	27	21	92

Of the 51 MIT students enrolled, 41 are currently recipients of Army ROTC scholarships and five others have applied. These scholarships pay full tuition, a monthly allowance of \$100, and a once a year textbook allowance of \$360. The value of these scholarships to MIT for school year 1985-86 was \$517,707. We anticipate that for school year 1986-87, approximately 50 MIT cadets will be on scholarship with a value to MIT of approximately \$672,550.

This year the Army ROTC Department commissioned 19 new second lieutenants, nine of whom were from MIT. Of the 19, five are entering medical school, eight others will be reporting immediately to active duty, three are going into the Army Reserve, one is staying at MIT to obtain his Master's Degree at full government expense, and one other has a full academic year until he receives his MIT undergraduate degree. Our commissioning mission, as set by our higher headquarters for this school year, was 18 so we did successfully meet our mission.

This year we were fortunate to be one of only 20 ROTC units across the United States chosen to participate in a test program designed to give the Professor of Military Science a large amount of decision-making authority heretofore reserved for our three higher headquarters. The three most important elements of this test program were the ability of the PMS to grant approval for scholarship students to change their academic major and still retain their scholarships, the ability to approve medical waiver requests for students who have a minor medical condition that we feel will not hinder their performance in ROTC and the Army, and finally, the ability to award 20 scholarships directly to students we feel are best qualified. Six of these scholarships went to six members of the MIT class of 1990, ten went to current members of the freshman class, and four went to current sophomores. All 20 recipients have until the start of the 1986-87 academic year to decide whether or not they will accept the scholarship offer. A final decision as to whether this test program will be expanded to all 314 ROTC Detachments, or whether it will be modified or ended completely, will be made this summer. We anticipate that elements of the program will remain, but major decision-making authority actions such as the awarding of scholarships will be returned to higher headquarters.

During the year, Army ROTC again sponsored the Annual Tri-Service Awards Banquet with over 125 cadets receiving awards from 45 different organizations. \* President and Mrs. Gray and several MIT representatives along with representatives of the Tufts and Wellesley administrations attended the banquet. The guest speaker was United States Army Reserve Brigadier General Mark W. Tenney, a 1958 MIT Army ROTC graduate who was commissioned into and still remains in the Army Reserve. Army ROTC also participated in various Tri-Service events sponsored by the other services such as the Military Ball, Field Day, other athletic competitions, and on April 30th, the Annual Tri-Service Pass and Review and Parade with President Gray as the Reviewing Officer.

On and off campus learning experiences continued to be expanded this year as cadets were given the opportunity to train on more Army weapons systems, were familiarized with more "state-of-the-art" systems, and were again flown from Briggs Field on MIT to Fort Devens, Massachusetts, in Army UH-1 helicopters. Also an MIT Student Chapter of the Society of American Military Engineers was chartered, and enrollment increased in the MIT Pershing Rifles Company, a group of both ROTC and non-ROTC students dedicated to the pursuit of military tactical excellence and patriotism.

The ROTC Faculty Committee, under the chairmanship of Professor Robert MacMaster, continued to provide timely advice and support of the ROTC programs. Members of the Committee, along with other members of the faculty and Lincoln Labs, participated in 22 scholarship boards throughout the year. The professional evaluation of scholarship potential rendered by members of the MIT community will be of great value to each applicant and to the Army.

Of the nine-person Army ROTC staff, two new personnel arrived this year--Major Adrian Serafini is a member of the Massachusetts Army National Guard and Major Richard Kury is an Army Reservist. The assignment of these two is intended to provide a perspective to our cadets of the lifestyles and military responsibilities associated with assignment to the Reserve or National Guard. (Nationwide, 50% of the 8,000 new lieutenants each year are assigned to the Reserves or National Guard.) Three cadre members, to include myself, are departing at the close of the school year. The incoming Professor of Military Science, Lieutenant Colonel Edward D. Hammond, is no stranger to MIT or

Massachusetts. He currently lives in Winchester, works in the Waltham office of the New England Division Engineer, and earned both of his Master's Degrees from MIT in Civil Engineering and Economics. Also of particular note is the fact that Ms. Mary J. Hovnanian celebrated 40 years of dedicated service to the MIT Army ROTC Department in May. Her services, as always, are invaluable.

LIEUTENANT COLONEL JAMES P. HASSETT, ARMY ROTC

#### NAVY ROTC

Student enrollment as of September 10, 1985 is shown below:

	Freshmen	Sophomores	Juniors	Seniors	Total
MIT	35	20	24	19	98
Harvard	24	13	10	9	56
Tufts	9	5	11	2	27
Wellesley	1	1	0	0	2
Total	69	39*	45	30	183

\*Includes two non-scholarship college program midshipmen (one MIT, one Harvard).

On June 3, 1986 a Tri-Service Commissioning Ceremony was held onboard the USS CONSTITUTION at the Charlestown Navy Yard, Boston, Massachusetts, in which President Grady participated. Vice Admiral Joseph Metcalf III was the guest speaker. Of those commissioned, 27 were graduates of the NROTC program. Not included in the June count are two fifth-year midshipmen, one commissioned in February 1986, and the other anticipating an August 1986 commissioning.

Highlights of the year included:

1. Visits in November 1985 by Rear Admiral Simon, Mess Night guest speaker, and in February 1986 Brigadier General Joy, USMC.
2. Field trips to Submarine Base New London, Connecticut; Naval Air Station South Weymouth, Massachusetts; and two field trips to NETC Newport, Rhode Island. Fred Massey of the ROTC Committee accompanied the second group to NETC Newport.
3. The Tri-Service Ball, Tri-Service Awards Banquet and the Tri-Service Pass-in-Review rounded out an ongoing Tri-Service athletic competition. In addition, this year NROTC midshipmen and AFROTC cadets exchanged views during respective drill periods to become more aware of the ROTC program in general.
4. Orientation was conducted in August for incoming freshmen. Drill, military knowledge classes and physical training were augmented by a rappelling session at Fort Devens, Massachusetts.

Personnel changes included:

1. Captain Matthew Taylor, USMC relieved Captain Harold Bonham, USMC as Battalion Advisor and Marine Officer Instructor.
2. Quartermaster Chief Petty Officer H. Bradley McCracken, USN relieved Master Chief Petty Officer Garrett Schultz, USN as Assistant Navigation Instructor.
3. Storekeeper Chief Petty Officer Linda Potts, USN is expected to relieve Storekeeper First Class Ernest Schreiber, USN who detached in May. Assumption of storekeeper duties is expected September 11, 1986.
4. Lois Zaks joined the staff as part-time receptionist in March 1986.

The year was both successful and challenging. Maintaining program excellence in the face of growing NROTC enrollment was achieved through setting and meeting goals related to effectively counseling midshipmen and to improving the conduct of review boards. Particularly gratifying were the positive comments of faculty members participating in review boards. Testimony was given as requested by the Faculty Committee on Military Research at MIT, the Student Affairs Committee, and the ROTC Committee, as well as by various faculty members. An investigation following a December arson incident was

inconclusive; steps were taken to improve security without impeding access to Building 20. Seamanship and Marine Corp preparation remain in place with the Tech dinghies, the 41-foot sailboat PATRIOT, and our "Semper Fi Society." This year an aviation society (the "Goshawk Association") was formed. The goals of this voluntary group are to provide an opportunity for increased understanding of and appreciation for Naval Aviation, as well as to better prepare Institute graduates selected for Navy flight training. An additional goal is community service.

COMMANDING OFFICER V.P. MCDONOUGH

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## MIT/WHOI Joint Program in Oceanography and Oceanographic Engineering

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In 1985-86 the MIT Joint Program with the Woods Hole Oceanographic Institution (WHOI) hit an all-time high in its graduate student enrollment, with a total of 115 students registered throughout the five disciplines of physical oceanography, biological oceanography, marine geology and geophysics, chemical oceanography, and oceanographic engineering. In addition, there was a dramatic rise in the number of applicants to the program for the 1986-87 academic year, a statistic which is contrary to the downward trend in the number of applicants to graduate schools in oceanography nationwide. The total number of applications for 1986-87 was 152, an increase of 33.3 percent over last year's figure of 114. Of these, 43 were offered admission, 27 of whom accepted. Of our incoming students, two will be bringing NSF Fellowships to the program, and one of our geochemists was awarded an Ida M. Green Fellowship for the 1986-87 academic year.

During 1985-86 the program graduated 15 students, all with doctoral degrees. Of these, there were seven in oceanographic engineering, three in biological oceanography, two in chemical oceanography, two in marine geology and geophysics, and one in physical oceanography.

Projected enrollment for September 1986 is 125 students registered throughout six MIT departments. Of these 125, 34 will be in physical oceanography, 28 in marine geology and geophysics, 26 in oceanographic engineering, 19 in biological oceanography, and 18 in chemical oceanography. We are particularly proud that almost 40 percent of our total number of graduate students are women.

In the fall of 1985, the program reached a milestone when our first class was transmitted via the two-way microwave link set up between MIT and WHOI. Unfortunately, Hurricane Gloria created a temporary setback when high-speed winds struck down the repeater tower at Monk's Hill, Kingston, MA. After repairs were made, the link was used successfully for the regular transmission of four weekly classes (plus various seminars and meetings) between MIT and WHOI during the 1986 spring term. Development is currently under way to link the computers between the two institutions. The operation of the microwave link promises to be an important component in many future joint efforts.

MARY ATHANIS

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## Office of the Dean for Student Affairs

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### INTRODUCTION

Fiscal Year 1986 for the Office of the Dean for Student Affairs (ODSA) was one of significant change and unique opportunity. The year began with a change in reporting structure for the ODSA from the Vice President in the Office of the President to the Associate Provost in the Office of the Provost. Simultaneously, there was a reporting change for the Office of Minority Education from the Associate Provost to the Dean for Student Affairs.

Several staff and Housemaster changes occurred during the year and these are described in some detail in the attached reports from the various ODSA sections. Paramount among these changes was the retirement of Dean Eugene Chamberlain following 32 years of dedicated service to the Institute, including 21 as International Student Advisor. His wise counsel and devotion to students will be sorely missed. Other major changes included the resignations from the Institute at the end of the fiscal year of Deans Holliday Heine and Robert Sherwood to pursue other career interests. We are deeply indebted to each of them for their significant contributions over the years to student life while serving in the Dean's Office.

We were heartened by the arrival in October of Dr. Joyce Gibson as Director of the Office of Minority Education (OME) and by the appointment of Dr. David Wiley as Associate Dean and Head of the Undergraduate Academic Support section, effective next month. Under Dr. Gibson's outstanding leadership, several important changes have already taken place in OME and these are described in some detail in an attached report.

The creation this year of the position of Dean of Undergraduate Education (DUE) and Professor Margaret MacVicar's subsequent appointment to that position represent exciting opportunities for joint ODUE/ODSA initiatives and such cooperative efforts are beginning to develop.

Significant changes and opportunities have also occurred in the program area. Following months of discussion with faculty, staff, and students, several initiatives have been developed that are designed to strengthen freshman advising and to provide greater opportunities for informal, intellectual interactions between faculty and freshmen. These will be implemented as a three-year experiment to begin this fall. We are indebted to the many faculty, staff, students, and faculty committees who so generously shared their thoughts on this proposal with us and to all of the department chairmen who assisted us in the identification of faculty participants. We are extremely pleased that Professor Travis Merritt has agreed to direct this very important effort.

Several of these initiatives will be based in the living groups, as were the discussions associated with this year's very successful colloquim series that resulted from the exceptional and tireless efforts of Professor Frank Morgan and the substantial support of Associate Provost Jay Keyser.

In a second program area, a committee was established to review the Housemaster-Tutor System. This Program was last examined in depth in 1973 and it was felt that we needed to determine whether the current system was adequately addressing the needs of residential students and the goals of the residential program. We are very fortunate to have Dean Gerald Wilson serving as chairman of the evaluation committee.

The Minority Student Issues Group (MSIG) completed its second full year of discussion of issues related to the recruitment, retention, and the quality of the undergraduate experience of MIT's minority students. This group has grown from four people in the Fall of 1984 to more than 25 faculty, staff, and senior administrators from around the Institute. A major MSIG achievement this year was the conduct and analysis of a telephone survey of Black alumni regarding their undergraduate experience.

A draft report on the survey results, written by Dr. John Wilson and Dr. David Wiley, has been discussed with several major groups, including the Academic Council and two of the five School Councils. The report reflects experiences that were generally negative and highly critical of the living and learning environments at the Institute. Using the survey report and other sources, the MSIG has as a major goal for the fall the development of a long-range improvement plan that will make recommendations regarding ways the Institute, through its faculty, staff, and students can qualitatively affect the minority undergraduate experience.

A companion group of minority and non-minority students has also begun meeting and initial indications are that this will lead to better understanding and improved communications between students with the possibility of some joint initiatives aimed at the larger student community.

Within the Office, we have taken the first step (computer purchases) towards the creation of a computer network that will electronically link the geographically dispersed sections of the ODSA. In the coming year, we will develop the network to the point that we can share data and other information within the Office and improve communications and services through the use of electronic mail and scheduling capabilities of the network.

Communication between students and the ODSA staff continued to improve this year through several informal social activities and through working closely on several important issues affecting students, some of these efforts are described in the sectional reports that follow.

We were very pleased with the exceptional leaders of various student groups and organizations. Especially impressive was the outstanding leadership of Bryan Moser, Undergraduate Association President, of Jeanine Nell, Graduate School Council President, and of Carol Morris, Black Students' Union President.

Much has been accomplished again this year, thanks to the dedication, energy, and enthusiasm of a very talented and resilient staff who enjoy working with and on behalf of students. The work of the Central office has been significantly enhanced by the addition of Marilyn Bodnar as Administrative Officer for the ODSA.

SHIRLEY M. MCBAY

#### UNDERGRADUATE ACADEMIC SUPPORT

The Undergraduate Academic Support (UAS) Office coordinates the freshman and undesignated sophomore advising programs; the orientation programs for all new undergraduates; and serves as an academic information center for students, individual faculty members, and departments. The office also serves as the administrative support structure for the Faculty Committee on Academic Performance, the January Independent Activities Period, and the Wellesley-MIT Exchange Program. The major UAS programs are described below.

##### Freshman Advising Program

The primary counseling of freshmen during 1985-86 was carried out by 261 advisors (140 faculty, 12 lecturers/instructors, 19 research staff members, 29 graduate students, and 61 members of the administrative staff). These advisors were supported by nearly 250 undergraduates who served as "associate advisors."

Eight freshmen withdrew for a variety of personal reasons during the academic year. Ten additional freshmen were required to withdraw for at least one term because of unsatisfactory academic performance. The table below summarizes for the past four years actions by the Committee on Academic Performance regarding unsatisfactory academic performance as well as the number of the more informal letters from our office suggesting that the student review his or her performance.

<u>Academic Year</u>	<u>Required Withdrawals</u>	<u>CAP Warnings</u>	<u>UAS Letters</u>	<u>Total Academic Actions</u>
1985-86	10	93	73	176
1984-85	13	79	53	145
1983-84	12	96	89	197
1982-83	17	109	73	199

##### Undesignated Sophomore Advising Program

Twenty-nine faculty and staff advisors counseled the 61 students who chose not to declare a major at the beginning of their sophomore year. By the spring term, the number of undesignated sophomores had decreased to 14. The respective student figures for 1984-85 were 69 and 30 for the fall and spring terms.

### Supervision and Coordination of Residence/Orientation (R/O)

Our fall term residence/orientation program, designed to welcome all new undergraduates and produced almost entirely by students, was under the leadership this year of R/O co-coordinators, G. Win Treese and Suzanne Horine. Highlights of this year's R/O activities included the unplanned but still successful holding indoors of both the Freshman Picnic and the President's Reception. Both activities were rained out as outdoor events for the first time in 15 years.

In late September, Associate Provost S. Jay Keyser formed a committee to evaluate and improve the orientation of new students. A permanent evaluation process for R/O is expected to evolve from this Committee's efforts.

### Administrative Support to the Committee on Academic Performance (CAP)

The CAP was chaired this year by Professor Vernon Ingram. During the year, the Committee handled approximately 400 petitions from individual students requesting readmission and exceptions to certain regulations of the faculty. A total of 76 Required Withdrawals (approximately 2 percent of the undergraduates) and 366 Warnings (approximately 9 percent) were voted for the academic year. These figures were distributed by class as follows:

	<u>Required Withdrawals</u>	<u>CAP Warnings</u>
Class of 1986	13	58
Class of 1987	24	97
Class of 1988	29	118
Class of 1989	10	94

The CAP office also operates as an information center for academically-related policies and procedures.

### The Undergraduate Seminar Program

While there was a decrease from last year in the number of offerings in the Undergraduate Seminar Program (from 49 to 44 in the fall semester and from 37 to 35 in the spring), the number of students participating in the program increased. Approximately 1,320 students (including 704 freshmen) enrolled in seminars, compared to 1,170 students (694 freshmen) last year. This underscores the importance of the seminars as a complement to the regular curriculum. The number of seminars is expected to increase next year with the addition of special freshman seminars. This year Associate Provost Jay Keyser served as chairman of the program.

### Independent Activities Period (IAP)

Interest in the IAP period has never been higher. The number of IAP activities rose to 681 from 620 in IAP '85, with 30% of the faculty participating in these activities. At the same time, the review of undergraduate education that is currently underway by various committees throughout the Institute, has included questions about the future structure and content of IAP.

This year was Professor Shaoul Ezekiel's fourth and last year as chairman of the IAP Policy Committee. During that time, he provided committed and energetic leadership to the program. He will be succeeded by Professor David Gordon Wilson.

The IAP Guide was placed on the Project Athena network this year. Not only were activity leaders able to submit their listings via the computer but students could call up updated IAP listings during January. In many ways, this year's system was a test, and it will be improved in future years.

### Wellesley-MIT Exchange

For the seventeenth year the Wellesley-MIT Exchange Program offered MIT and Wellesley students the opportunity to experience a different educational institution and to expand their academic programs through cross-registration.

The number of students cross-registering was comparable to previous years. In the fall semester, 140 MIT students registered for 166 Wellesley subjects while 167 Wellesley students took 220 MIT subjects. As in the past, the number of cross-registrants increased in the spring: 161 MIT students enrolled in 188 Wellesley subjects and 196 Wellesley students in 256 MIT subjects. Among the cross-registrants were two MIT chemistry majors (Mario Gonzalez and Karen Sheehan), who earned certification as secondary school teachers through the Education Department at Wellesley.



In addition to cross-registration, the Exchange continued to administer a small residence exchange program involving approximately 10 students from each school.

While students did most of the traveling between the two schools, three members of the Wellesley Faculty commuted to MIT. During the first semester, Professor Roger Johnson taught Crises of Belief in Modern Religion and in the spring Assistant Professor James Kodera offered Introduction to Asian Religions. In addition, Professor Michio Tsutsui was at MIT full-time both semesters teaching beginning and intermediate Japanese.

Professor Robert Silbey continued as MIT co-chair of the Wellesley-MIT Joint Committee. A six-person steering committee composed of faculty and administrators from both schools now meets monthly between meetings of the full Joint Committee.

#### Academic Support and Information Center

Activities in this area are designed to improve advising and teaching programs for undergraduates. Examples of expanded or new efforts include the following:

- 1) Assisting the Graduate School Office in conducting the second annual orientation and workshop for new teaching assistants in the Fall of 1985.
- 2) Preliminary planning for a one-day orientation and teaching workshop for new faculty for the Fall of 1986. This will be a specific extension of the workshop for Teaching Assistants.
- 3) Working with the Systems Dynamics Group on a Project Athena proposal to prepare "The Tooling Game," a computer simulation of typical choices a student has to make during the course of the semester in order to understand how interdependent those choices are.
- 4) Sponsoring Study Skills programs during the fall and spring semesters, and over IAP. The fall program, entitled Survival with Style and presented by two seniors, attracted 15 percent of the freshman class.
- 5) Identifying, for the Minority Student Issues Group, a way of pinpointing student performance that is significantly different from what the usual admissions indicators would predict.
- 6) Creating and supporting an Associate Advisor Steering Committee designed to utilize this valuable resource more fully. This committee prepared a guide book and ran a recruitment and information program for Associate Advisors.

#### Career and Course Orientation

We continue to participate in a number of efforts designed to improve information available to students about career opportunities open to them. These include:

- Publishing departmental "Roadmaps" which encourage advisors to work actively with their freshmen in discussing course options.
- Working closely with departments in the planning and coordination of spring term departmental "Open Houses."
- Stocking resource information about departments and disciplines in the UAS "Reading Room."

#### Staff

The past year has been one of tremendous change and unsettled periods within the section. Within that context, however, we accomplished a great deal of which we are quite proud as described in the summaries above.

Staff changes within the section were as follows:

- Andrew Eisenmann, of the Residence and Campus Activities section, joined the UAS staff on a half-time basis, switching positions with Barbara Chuck.
- Margaret Richardson, who was serving as Executive Officer, left the section and now holds the position of Assistant Dean for Undergraduate Education. Mary Enterline has assumed the Executive Officer's responsibilities.
- Holliday Heine has resigned as Associate Dean and Section Head effective June 30. Her successor will be David Wiley.

In addition, UAS staff continued to serve on the traditional committees as summarized last year.

HOLLIDAY C. HEINE  
ANDREW M. EISENMANN  
MARY Z. ENTERLINE  
JEFFREY A. MELDMAN  
STEPHEN M. PATTERSON  
MARYGLENN VINCENS

#### STUDENT ASSISTANCE SERVICES

Students find their way to the Student Assistance Services (SAS) for a variety of reasons. Some come in crisis; some simply for help with issues common to a college age population; and some have matters related to visa status. The Office is organized so that diverse needs are served and access is easy.

#### International Students

The 2776 scheduled student appointments during the year included 837 students who came in about matters relating to their status in this country.

There were two international tragedies during the year that drew on MIT resources for support. In September, the Mexican earthquake galvanized the community. In addition to cash collected for relief efforts, a series of lectures was sponsored during IAP on Mexico. The Colombian volcano tragedy in November of 1985 again brought out the best in the MIT Community and our office helped coordinate efforts to gather relief funds for Colombia.

In November, the office sponsored a trip to Sturbridge Village to improve and increase cross-cultural communication and understanding by promoting interaction between domestic and international students. Forty students participated in this very successful effort and plans are to repeat it next year.

#### Special Student Groups

Since joining the staff, Jacqueline Simonis has made women students a primary focus. She has attended regular monthly meetings of the MIT Women's Advisory Group and the Advisory Committee on Women Student Interests. A special effort was made to reach out to women's living groups, resulting in contact with McCormick Hall, Green Hall, and WILG.

Lynn Roberson, Staff Assistant for women students, continues to produce the Cheney Room Papers, a compilation of articles and events pertinent to women at MIT. She provides staff support to the Women's Advisory Group, the Advisory Committee on Women Student Interests, and to Residence/Orientation planning for women students.

Groups, discussions, and workshops offered to women students this year spanned such subjects as harassment, assertiveness, and issues facing graduate women and international women. Guests spoke on such topics as "Black Women in the Political Process", "...Dilemmas for Women of Color", and "Women, Competence and Self-Perception".

Current planning for MIT women is focused on tapping the diversity of women's voices at MIT. Presently under discussion is the formulation of a Women Students' Advisory Board. The Board would comprise representatives from living groups and women's activities who would advise the Dean's Office on needs, hopes, and frustrations of women students at MIT. Also being considered is the linkage of a speakers' series with sponsoring student organizations, to boost attendance and publicity. Finally, a meeting has been scheduled for key people at MIT to define a network of resources for students struggling with food, eating, and body image issues under Dean Simonis' guidance.

Nightline, with Dean Simonis' guidance, continues to provide an important alternative resource to students who have informational questions, personal concerns, or who just want to chat with a peer. In addition to staffing phone lines from evening until morning throughout the term, Nightline sponsored a week-long series of workshops on relationships this spring. Topics included balancing careers and relationships, the vicissitudes of relationships, and health/sexuality issues. Workshop facilitators were recruited from Dean's Office staff, the Medical Department, and from outside MIT. Nightline also participated for the first time in a training program for associate advisors. SAS staff collaborated with the Nightline supervisor to formulate a presentation on peer counseling which was very well received.

Support for the minority community was given ably during the first portion of the year by Dean Janice Cooper before her departure. During the winter and spring, Dean Leo Osgood picked up some of the slack and the improved working relationship between the ODSA and the OME made it possible to continue programs. Janice Cooper served an important role as a link with the past and as the initiator of new directions for the future. Marilyn Braithwaite steps into a situation that is much improved.

The efforts of the Office to formally support the diverse segments of the community have continued despite staff shortages and the challenge of change. Especially noteworthy were the efforts to support the Committee on Foreign Scholarships and the Committee on Discipline. A new document revising the Rules and Regulations of the Committee on Discipline resulted from the efforts of Dean Osgood and Professor Elias Gyftopoulos, Committee on Discipline Chairman. Drawing on the experience of the last few years, and Professor Gyftopoulos' experience over an even longer period, the new document should serve to guide the Committee effectively into the next decade.

The trip to Taiwan by Dean Robert Randolph provided some needed perspective on other educational systems and a sense of the background from which the largest segment of our international community comes. If we are to develop an agenda for dealing responsibly with the international students we attract, it must begin to take shape. Secondly, this office will be able now to program more effectively for the diverse constituencies we serve.

At the same time we are being asked to take on more and more responsibility - e.g., co-sponsoring the Black Alumni and Students Science Conference, and The Martin Luther King Celebration. What we should do, what we want to do, and what we can do are converging. A new reality will emerge and we believe SAS will be a support office with priorities in place and the ability to accomplish the goals we set.

#### Staff

In September, Linda Vaughan left to become the Dean of Students at Lesley College. In January, Janice Cooper left to join the Office of Economic Opportunity in the Dukakis administration. At the end of the current year, Leo Osgood will become the head basketball coach at MIT and will as such be part of the faculty. He will remain involved with the ODSA as Dean-on-call. Gene Chamberlain will be retiring at the end of the year after more than 32 years at MIT. He has served as Foreign Student Advisor for 21 years.

The search is currently underway for Dean Chamberlain's replacement. The other positions have been filled. Jacqueline Simonis joined the staff in January, having just finished her doctorate in counseling and administration at Harvard. Arnold Henderson and Marilyn Braithwaite join the staff for the new fiscal year. Arnold comes from Brandeis and Marilyn is from Tufts. With the addition of a new Foreign Student Advisor, we will have three new staff members to orient over the course of the summer. The prospects for breaking new ground are exciting.

ROBERT M. RANDOLPH  
EUGENE R. CHAMBERLAIN  
LEO OSGOOD  
LYNN ROBERSON  
JACQUELINE SIMONIS

#### RESIDENCE AND CAMPUS ACTIVITIES

##### Institute Houses

The crowding in the Institute Houses was the most severe it has been since 500 Memorial Drive opened in 1981. Almost 200 rooms had to be crowded in order to accommodate all of the undergraduates choosing to live in the House system. The total number of students affected was between 500-550. A bright note for freshmen was that, on the first round of dormitory assignments, 95.7% of them received their first choice dormitory assignment.

The excessive crowding was due to two main factors: (1) the freshman class came in at 35 more freshmen than was targeted; and (2) the return rate for upperclass residents is at an all-time high of 97%. For the fourth straight year, the class size target has been exceeded by approximately 35 students, resulting in the steady state of an additional 140 students in the residence system than expected.

Given this situation, the President has decided to reduce the target size of next fall's incoming class from 1025 to 975. Another solution being proposed is to obtain non-Institute housing for the approximately 65 women of Alpha Phi Sorority, who are currently living on campus but are anxious to find an off-campus home.

Serious problems also remain in the housing of graduate students on campus. With a constantly increasing entering graduate class size (1450 this past fall), a smaller percentage is able to obtain on-campus housing. This year 928 (64%) of the new graduate students applied for on campus housing, and only 260 (18%) could be accommodated, leaving a waiting list of 668 (47%). Since there is no upper limit on how long graduate students may remain in on-campus housing, the turnover rate is very low. A two-year tenure limit has been proposed, but would not significantly increase the number of available spaces, if implemented.

Thanks to the efforts of many people, discussions are now underway that should ultimately lead to the construction of new graduate student housing units within the next few years.

#### Faculty and Graduate Resident Program

As reported last year, Professor and Mrs. Vernon Ingram and Professor and Mrs. Robert Kennedy became Masters at Ashdown House and MacGregor House respectively.

Also joining the system in 1985-86 as Faculty Resident and Junior Faculty Resident respectively at East Campus were Professor Daniel Osherson, of the Department of Psychology, and Dr. Brian Harvey of Media Arts and Sciences.

Housemasters departing from the residence system at the end of the 1985-86 academic year were:

Professor and Mrs. Judah Schwartz, who served as Masters in Bexley Hall from 1980-1986;

Professor Margery Resnick and Dr. Stephen Ault, McCormick Hall (1978-86);

Professor Daniel Osherson, East Campus (1985-86); and

Professor and Mrs. Alan Hatton, MacGregor House Junior Faculty Residents (1983-86).

We are very grateful to these faculty families for their many contributions to the residential system over the years and look forward to their continued counsel.

We are pleased to report the appointment of the following individuals to the Housemaster Program:

Professor and Mrs. Tunney Lee, Department of Urban Studies and Planning, at East Campus;

Professor and Mrs. Frank Solomon, Department of Biology, at Bexley Hall;

Professor and Mrs. Graham Walker, Department of Biology, at McCormick Hall; and

Professor and Mrs. Amiram Moshaiov, Department of Ocean Engineering, at MacGregor House as Junior Faculty Residents.

The monthly Housemaster dinner meetings this year have been modified at the request of the Housemasters to use an executive committee format to help set agenda, draft policy statements, etc., for the monthly meetings and the new format has worked very well. A Housemaster Review Committee has also been appointed by Dean Shirley McBay. The committee, chaired by Professor Gerald Wilson, Dean of the School of Engineering, will review the current Housemaster/Tutor program and explore a new vision for the future.

### Dining Program

The Dining Advisory Board met during the Spring Term to discuss a proposal to contract out all dining services on campus (Faculty Club, Student Center, House dining halls, and catering).

A Food Service Management Company Search Committee was established to review proposals and meet with representatives from seven companies bidding for the food services contract. This group has made its recommendations to the Senior Vice President.

Meetings were also held with Food Service staff, Dean's office staff, and Commons Committee students in each of the commons houses to discuss and to resolve operating unit problems.

### Institute Colloquim Committee

Judith Douglass served as a member of the Executive Committee of the Institute Colloquim Committee and chairperson of the Living Groups Committee. She helped to coordinate evening discussions between faculty, staff, and students in several living groups for each of three major workshops: Apartheid, AIDS, and Economic Competitiveness. These proved to be excellent opportunities for informal interaction between students, faculty, and staff in a living group setting.

### Fraternities/Sororities and Independent Living Groups

Alpha Chi Omega National Women's Fraternity was colonized and chartered this year, offering an additional choice for the women at MIT. Alpha Chi Omega has indicated that, at present, it has no desire to seek separate housing for its members. Another major focus this year was to strengthen the support for Graduate Resident/Tutors in the Independent Living Groups.

The most pressing issues for the IFC groups this year were neighborhood relations, particularly for those houses in Back Bay and Brookline; developing community standards for off campus behavior; the new Massachusetts Hazing Law; the legal liabilities of alcohol consumption since the new 21 year old drinking age law; and declining male and increasing female matriculation.

The IFC took a leadership role at MIT by developing its own Hazing Policy to reinforce the new Massachusetts law on hazing. One serious hazing incident occurred in one of our fraternities, which was subsequently adjudicated by the Faculty Committee on Discipline, resulting in the suspension of two students from MIT and several others being placed on formal disciplinary probation.

The future holds demanding challenges for the fraternity system. The biggest is developing a plan of alternatives to remaining in the City of Boston. The increasing percentage of women in entering classes also represents a particularly positive challenge as we look for alternative housing.

### Campus Activities

The Campus Activities program was highlighted by a year of building (new staff, more the 20 new student activities bringing the total to 233) and systems refining. Programs run by student groups were diverse ranging from an alternative jobs fair, and the comedy of George Carlin to the creation of a shanty town which stood on the Kresge oval for 10 days. The Undergraduate Association, under the leadership of Bryan Moser, had its best year to date, responding to such diverse issues as educational policy and reform, tenure, alcohol, and pornography. Staff from our office were involved in all levels of these activities, through planning, advising, funding, and evaluation of programs. The pilot year of our structured leadership programs was met with success and received favorable response from both undergraduate and graduate student participants. The transition project for the student center is a reality as funding has been secured and architects are being selected. The project will offer the community a mix of food and retail options as well as improve the current ambiance of the building.

This year was the most active in many years with respect to student activism. Demonstrations occurred throughout the Spring Term on such issues as Divestment from South Africa, Strategic Defense Initiative (SDI) Funding, and the denial of tenure to Professor Frank Morgan. Several students were arrested for disorderly conduct and trespassing when they refused to leave Kresge Oval and allow for the removal of the Shanty Town which had been erected on that site.

The year also saw many birthday celebrations, including the 20th birthday of the Stratton Student Center, the 50th birthday of Alpha Phi Omega Service Fraternity, and the 125th (Quasqui- centennial) celebration of MIT's founding.

### Alcohol Policy and Party Registrations

During R/O week we held our first "dry rush", which went very well due to the excellent cooperation of the interfraternity conference and dormitory council. Alcohol Education sessions were also sponsored by the RCA Section and attended by student representatives of all 47 living groups before R/O week got underway.

The raising of the drinking age to 21 years of age has had a dramatic effect on undergraduate social life. There are fewer large parties on-campus and, thus, fewer alcohol requests. Fewer large parties does not necessarily mean less drinking, however. Most living groups have opted for smaller, more private entry or floor parties to eliminate the non-residents and to evade the necessity of registering their parties with the ODSA and Campus Police.

With more than two-thirds of the campus now underage, students recognize the new liability and responsibility which they assume by sponsoring and hosting an alcohol event for their dormitory. As a result, most students are reluctant to take total responsibility for major events and are just not advertising their events beyond word of mouth. Fear of legal liability is driving parties "underground" and away from the scrutiny of campus officials.

### Non-Resident Student Association (NRSA)

Two years ago, we closed the NRSA building for some necessary safety renovations. At the same time, we evaluated the viability of the student association using that facility. NRSA was allowed to continue using the facility but it was evident from the evaluation that the future of one of the oldest student organizations was bleak. This past fall, there were only 360 non-residents in the undergraduate population many of whom are married or upper class students who are not looking for a living group experience. Despite efforts by the NRSA, the facility has never been popular with graduate students. Thus, this spring the remnants of the NRSA leadership, faced with fewer than 30 active members, decided they could no longer manage the facility effectively and that they should turn the building back to the Institute for use by another student group.

### Graduate Student Housing

The most exciting development this year affecting graduate students at MIT concerns the announcement that, as soon as it is feasible, the Institute will construct a new graduate residence. No details on the size or type of housing are available at this time, but the ability to construct such a facility came as a result of several developments. The Graduate Housing Reserve Fund which was created to fund housing projects for graduate students has grown to a point where it can provide seed money for a building loan. Secondly, the last project for which those funds were committed, Green Hall, will be paid off next year which will free up the funds to support construction of new housing. One other factor in the decision is that the rental rates which would have to be charged to retire a loan on such a new residential facility are now quite comparable to market rates for off campus housing and not out of reach of student budgets. A site study is underway to determine appropriate campus and off campus areas suitable for development. A report is expected before the end of the summer, with a client team to be created early in the fall.

Ashdown House has been active this past year in developing plans for changes to their facility. Plans to renovate a portion of the basement to accommodate an additional 30-35 graduate students have proceeded to a feasibility study by the Architecture Section of the Planning Office. Ashdown also hopes to activate a portion of the Campus Room for a coffee house similar to that in the Student Center.

### Graduate Student Council (GSC)

The GSC saw several long-standing issues brought to a successful resolution during the past year. The Council experienced a surge in meeting attendance and in committee representation and thus was able to work more actively on many issues with more student input. Much of the success of this year can be attributed to the energy and effort of the Council's President Janine Nell.

One specific action the Council took which will have a lasting effect on graduate student life at MIT was to approve a set of Graduate Student Rights and Responsibilities recommended by the Council's Academic Projects and Policies Committee. This document attempts to clarify guidelines for relationships between faculty and students, and offers standardized administrative procedures for Teaching and Research Assistants. The policies will be published in the Graduate School Handbook in 1986-87 and are currently under consideration by the Faculty Committee on Graduate School Policy.

A second major effort of the Council's Academic Projects and Policies Committee was the development, administration, and analysis of a survey to all graduate students on the two subjects of housing and academic relationships with faculty. A five page, 33-item questionnaire was distributed to over 4000 graduate students during registration in February and analysis of the 1611 responses is still underway.

### Talbot House

Talbot House has continued to enjoy popularity with a variety of groups from the MIT community. During the 1985-86 academic year, 111 different groups applied for use of the house and 47 groups, comprised of 971 individuals, visited the Institute's retreat house in S. Pomfret, Vermont. As a result the house was occupied 95 nights of the year with 188 meals served. During the year, Talbot House was occupied 37 weekends with 10 groups making visits during the week.

The house continued to attract all facets of the MIT community with representation from 7 academic groups, 11 living groups, 13 associations or clubs, 2 alumni groups, and 14 faculty/staff groups. January and February were the most active months with 15 different groups taking advantage of the winter sports season.

These attendance figures were accomplished despite Talbot House being closed for almost four months for the second phase of some long overdue renovations. The house now has a new kitchen and additional bathroom facilities. Stairways and access ways have been brought into agreement with fire codes and cleaning and storage space have also been provided.

### Athena Deployment

Deployment of Athena machines into the living groups moved a step closer to fulfillment this year as five living groups were chosen from over 20 applications from the dormitories and independent living groups.

A major hurdle in the past two years has been the question of who was going to pay for the deployment of the equipment. Students expected The Athena Project to provide for all installation costs while The Athena Project seemed to expect students and the living groups to pay their share of the renovations costs. A compromise was reached for the five pilot-phase houses as Athena will fund all costs associated with the first year to test hardware and communication methods to remote sites. The larger question of future installation costs to other dormitories and Independent Living Groups remains open.

### Discipline and Harassment Cases

A report of student discipline and harassment cases for AY 1985-86, adjudicated by RCA staff, is available in the ODSA. In summary, four students were suspended from their houses, three were suspended from the housing system, three were declared persona non grata, seven were placed on Dean's Office Disciplinary Probation, five were given a Dean's Office Disciplinary Warning, four were required to pay financial restitution, two were issued restraining orders, two were required to write letters of apology, and three were referred for professional counseling. An additional number of cases were dealt with through verbal warnings.

Offenses included assault and battery, assault and battery on a police officer, resisting arrest, setting fires, harassment, perjury, theft, destruction of property, verbally abusing a police officer, and disorderly conduct.

### Staff Changes

Dean Robert A. Sherwood has resigned to become Dean of Student Development at Boston College.

Assistant Dean Peter H. Brown has resigned to take a position as Associate Bursar for Management Information Systems at MIT.

Dr. Barbara Fienman's title has been changed from "Advisor" to "Director" of Campus Activities.

ROBERT A. SHERWOOD  
ANN BRADEN  
PETER H. BROWN  
BARBARA S. CHUCK  
JUDITH M. DOUGLIS  
ANDREW M. EISENMANN  
MARK E. ERTEL  
BARBARA M. FIENMAN  
RETA M. LEE

### Attachments to the ODSA Report:

Fall, 1985 Institute Undergraduate House Count  
Fall, 1985 Institute Graduate House Count

October 1985

FALL, 1985 INSTITUTE UNDERGRADUATE HOUSE COUNT

	1		2		3		4		Other		Total					
HOUSE	M	F	M	F	M	F	M	F	M	F	M	F	TOTAL	CAP	VACANCIES	CROWDS
Baker	44	38	58	37	58	22	50	44	3		213	141	354	337	0	17
Bexley	24	3	28	10	21	9	22	7			95	29	124	122	1	3
Burton	59	25	64	37	82	39	59	16	0		264	117	381	344	0	37
East Campus	64	22	70	42	68	27	78	22			280	113	393	363	0	30
MacGregor	92		73		82		98		1		346		346	328	0	18
McCormick		49		70		65		52		1		237	237	219	0	18
New House	42	20	32	22	38	14	49	10			161	66	227	208	0	19
French House	4	2	4	2	3	4	2	4	0		13	12	25	24	0	1
German House	3	4	5	1	1	1	4	1	1		14	7	21	21	0	0
Russian House	4	1	2	5	4	0	2	1			12	7	19	18	0	1
Spanish House	5	2	6	1	5	3	2	0			18	6	24	21	0	3
Random	16	7	16	5	15	4	23	7			70	23	93	93	0	0
Senior House	20	27	38	12	42	7	35	6			135	52	187	183	0	4
500 Mem. Dr.	68	59	47	32	53	28	58	41	3		229	160	389	352	0	37
TOTAL	445	259	443	276	472	223	482	211	8	1	1850	970	2820	2633	1	188
	704		719		695		693		9		2820					



FALL 1985 INSTITUTE GRADUATE HOUSE COUNT

	<u>Men</u>	<u>Women</u>	<u>Total</u>
<u>SINGLE</u>			
Ashdown	323 (83%)	67 (17%)	390 (100%)
Green	0 (0%)	46 (100%)	46 (100%)
Tang	340 (84%)	64 (16%)	404 (100%)
Graduate Residents	22 (61%)	14 (39%)	36 (100%)
	—	—	—
SUBTOTAL	685 (78%)	191 (22%)	876 (100%)
	<u>Men</u>	<u>Women</u>	<u>Total</u>
<u>MARRIED</u>			
Eastgate*	178 (87%)	26 (13%)	204 (100%)
Westgate*	198 (93%)	16 (7%)	214 (100%)
Graduate Residents*	29 (83%)	6 (17%)	35 (100%)
	—	—	—
SUBTOTAL	405 (89%)	48 (11%)	453 (100%)
TOTAL	1090 (82%)	239 (18%)	1329** (100%)

\*There are 7 couples in Eastgate where both members are students, 5 in Westgate and 4 Graduate Resident couples where both members are students.

\*\*Total normal capacity of all MIT graduate residencies is 1247 which does not include graduate residents, and includes only one member of 2 student couples.

OFFICE OF MINORITY EDUCATION

The 1985-86 year brought many exciting changes for the Office of Minority Education (OME). It was a year of review, evaluation, and re-dedication to the goals and purpose of the Office, which was established a decade ago. The following events characterize the changes which have had an impact on activities and programs this year.

1. A January, 1985 report of an Ad Hoc Working Group for the Office of Minority Education concluded that the services and programs of OME were as essential today to the optimal adjustment of underrepresented minority students as they were 10 years ago. Among its recommendations, the report included the need to place greater emphasis on research and program implementation, and for OME personnel to become more involved in the Institute at all levels.
2. On July 1, OME began reporting to the Office of the Dean for Student Affairs (ODSA). Though this was a change from reporting directly to the Provost's Office, OME continues to report to the academic side of the house, since the Dean's Office now reports to the Office of the Provost. The new leadership of Dean McBay has provided strong support, expansion of services to students, and greater involvement with academic and other student support offices.
3. Personnel changes brought new directions and new challenges to OME. Gloria Payne, budget and office manager who had worked in OME for 10 years took a leave of absence to complete a degree in Finance; Pearline Miller, the first assistant director of OME returned to the public school system and will begin doctoral studies soon. The challenge to new staff was to continue the service and support that years of experience had taught these pioneers in their work with minority students at the Institute.

The new staff include: Dallas Slawter, Assistant-to-the-Director; Tony Canchola-Flores, Assistant Director; and Joyce T. Gibson, Director. Donna Marie Horse Grant, joined the staff for several months as a consultant to assess the needs of Native American students.

### Programs

Over the years, programs and strategies have been initiated to support minority students' matriculation at the Institute. This year regular programs were continued and evaluated, while new initiatives were begun within the context of our objectives and the five-year plan completed through the ODSA. Many hours were also spent getting to know students and learning about the culture of the Institute in order to assist us in our assessment of program effectiveness. Our student staff added a student perspective to all our efforts, and played critical roles in our successful operation this year.

The academic support programs included the traditional evening tutoring program (BSU-TP); the seminar series on Institute Resources known as Strategies and Secrets of Academic Success (SSAS); and the peer advisory program, the Buddy System. The programs are designed primarily for freshmen, but are also attended by upperclass students. Together these three programs attracted over 250 students during the year.

New initiatives this year included: a joint sponsorship with the Writing Program of a writing tutor who worked spring term in the BSU-TP and in the Writing Center; collaboration with Course 16 during IAP for a review of the Unified curriculum for eight students; and the initiation of a new program with the Undergraduate Academic Support Office to monitor the academic progress of freshmen.

### Project Interphase

The 1985 Project Interphase program involved 40 minority freshmen who experienced a rigorous seven-week academic orientation to MIT. Professor Alan Davison served as academic officer for Project Interphase along with Professor James Gates who was the Acting Director of OME at the time.

A review of Project Interphase this year has resulted in changes in the program's organization and implementation. The revisions for the 1986 program include a new student selection process, a change in scheduling of classes, and some revision of the curriculum. Faculty support and student response to the changes have been positive. In addition, a new two-week session which will provide an overview of the freshmen year has been created. To date, there are 49 students enrolled for the seven-week session, and 20 for the new two-week program. Details about the 1986 program are available in OME.

### OME Advisory Committees

The OME Student Advisory Committee was re-convened with new members in October. Monthly meetings began in November and continued through May. Students representing the four underrepresented minority groups were invited to participate. Presidents of student organizations chose students for membership, while others were appointed by the Director.

The Faculty-Staff Advisory Committee was organized during the fall term, and began meeting in the spring. Faculty, administrators, alumni, and student representatives (from the student advisory committee) make up the membership of this committee. Both groups have played a vital role in the assessment and evaluation of programs and events this year.

### Student Support

OME staff have developed outreach strategies to get to know students and to involve them in OME and Institute activities. Early fall meetings with the major undergraduate minority organizations, BSU, LUCHA, APR, and an orientation with the students in BGSA began relationships which have matured and continued throughout the year. The office has co-sponsored or supported a variety of student programs and activities during the year.

### MITES/Second Summer

The MITES program continued to be organized and supported by Dr. Ernie Cravahlo. This year, the program is being administered by the School of Engineering under the auspices of Professor Jack Kerrebrock. OME and MITES staff have met with personnel in the School of Engineering to organize a joint fund raising effort to support the program. MITES is an important link for recruiting minority students and our staff supports the program's purpose.

Dr. Leon Trilling directed the Second Summer program this year. Our staff assisted in recruiting companies interested in placing minority freshmen in technical positions after their freshman year and we also helped with publicity to attract freshmen to the program.

### Minority Student Issues Group

The Minority Student Issues Group is a committee of approximately 25 administrators and faculty whose purpose is to discuss and address the adjustment of minority students at MIT. Chaired by Dean McBay, the group has aggressively pursued information from students, faculty and administrators about issues affecting minority students. Much of this committee's work, including the research and finding from their discussions and study, will lay the groundwork for programs and further research by OME. Both the Director and Assistant Director are active members of this group.

### Space Change

This summer OME will be moving to its new home in building 7, (7-143 and 7-145). This new move not only provides space to accommodate all the staff in one location, but will offer greater access to the other student support services and greater visibility Institute-wide.

We would like to thank our colleagues in ODSA, the students, and all our new friends in the Institute community who helped to make this an exciting and productive year for us. A special thanks to Dean McBay, Provost John Deutch, and Professors Ken Manning and Arthur Smith for their wise counsel and support.

Objectives for OME are listed below, along with enrollment figures for underrepresented minority students during the Fall, 1985.

### BROAD OBJECTIVES OF THE OFFICE OF MINORITY EDUCATION

1. To develop an introduction and orientation to MIT which will aid in the adjustment of minority students to the academic environment at MIT,
2. To foster greater participation of all underrepresented minority students in OME and the Institute,
3. To develop stronger ties and relationships with academic and other support offices in order to increase the visibility and credibility of OME,
4. To determine what variables or conditions influence student attrition and channel findings back into the MIT community in an effort to understand and address attrition.

### FALL, 1985 ENROLLMENT STATISTICS FOR UNDERREPRESENTED MINORITY STUDENTS

	American Indian	Black	Mexican American	Puerto Rican	<u>Total</u>
Undergraduate	15	219	90	71	395
Graduate	11	83	24	15	133
Total	26	302	114	86	528

JOYCE T. GIBSON  
TONY CANCHOLA-FLORES  
DALLAS SLAWTER

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## Facilities Use Committee

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Under the aegis of the Provost's Office the Facilities Use Committee formulates and implements policy for the use of Institute facilities by recognized MIT groups. The Committee reports to the Associate Provost for Educational Programs and Policy. The Committee's members this year were Stephen D. Immerman, Director of the Campus Activities Complex; Ronald Suduiko, Special Assistant in the Office of the Chairman of the Corporation; Mary Morrissey, Director of Information Services; Barbara Fienmann, Campus Activities Advisor; Winston E. Flynn, Associate Registrar; Gayle Fitzgerald, Manager of Conference Services; and Charlene Placido, Financial Assistant to the Dean of Science, Committee Chair. The Committee generally meets biweekly to review requests for the use of facilities and to discuss issues regarding policy, facilities charges, and related matters.

The Institute's tax-exempt status in part governs the use of MIT facilities. Facilities use should contribute to the enhancement of purposes for which the Institute has been chartered, with primary focus on its educational and research roles. MIT facilities may not be used to support candidates for public office or for lobbying for particular legislative issues, nor may the Institute's facilities be used to support profit-making organizations. The presentation by undergraduates of talks by candidates for public office is considered to be educational in nature, and therefore provision is made for the appearance of candidates for a variety of public offices.

The domain over which the facilities committee presides includes all of the academic space at the Institute, the Julius A. Stratton Student Center, departmental memorial rooms, and all similar spaces. Inevitably the Provost's Office and the facilities committee are drawn into broader issues involving controversial potential use of MIT facilities. As a consequence, the Office of the Provost is frequently consulted on a wide range of political, social, and even religious issues stemming from facilities use. For example, the appropriateness of activities suggested for IAP in January of each year has traditionally been reviewed in consultation with the Facilities Committee in addition to other appropriate sources within the Institute.

During the 1985-1986 year, the Institute hosted four major international meetings: the Twelfth International Symposium on Mathematical programming, the International Conference on Cryogenics Engineering, the Fifth World Congress of the Econometric Society, and the First National Conference of the American Institute of Graphic Arts. In addition, several national and regional meetings sponsored by MIT faculty members were held on campus. These conferences brought more than 6,500 people to the campus. In June the MIT Athletics Department sponsored, for the first time, the Massachusetts Special Olympics which attracted over 3,000 visitors including 1,500 athletes.

CHARLENE M. PLACIDO

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## Chairman of the Faculty

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This was the first year under the reorganized Faculty Committee structure approved by the Faculty last May. The Committee on Educational Policy was abolished and its responsibilities broadened and divided between two committees: the Faculty Policy Committee (FPC), chaired by the Chair of the Faculty, to serve as the senior standing committee of the Faculty (coordinating the policy-related activities of other standing committees and addressing a broad range of issues of concern to the Faculty), and the Committee on the Undergraduate Program (CUP), chaired by the new Dean for Undergraduate Education, to serve as the primary Faculty committee concerned with undergraduate education (developing and implementing educational policy, encouraging innovation and overseeing educational experiments, and exercising general oversight of undergraduate education, including the freshman year and other interdepartmental programs). The new structure has worked well in its first year, allowing the CUP to undertake the sustained effort that is needed to examine fundamental, long-range issues relating to the direction of an MIT undergraduate education and allowing the FPC to pursue a wide range of issues of significance to the Faculty.

The FPC, CUP, and the other Faculty committees addressed a number of important issues during the past year, which are highlighted in the following report.

### Faculty Policy Committee

Initial meetings of the committee were spent discussing its role and agenda, and its process for dealing with issues. In order to achieve more effective communication and working relationships with the other Faculty committees, the FPC met individually with most of the chairs to discuss the agendas for the year of the various committees. The FPC met three times with the Dean for Undergraduate Education to keep abreast of the review of the undergraduate program that is under way. The discussions with committee chairs provided a useful vehicle for sharing ideas, providing suggestions and direction, and in general helping to coordinate the work of the committees. Under the reorganization, all committees, including those with intense operational responsibilities, are encouraged to take on broader policy roles within their particular areas.

The FPC explored ways to identify issues of concern to the Faculty. An informal survey undertaken through a letter to faculty members from the Chair of the Faculty yielded a number of interesting and helpful suggestions. In conjunction with the officers of the Faculty, it was decided to provide a period for open discussions at some of the Faculty meetings; this concept will be initiated in the coming academic year.

A Housing Subgroup (chaired by Peter Elias) was established to explore concerns about the limited availability of housing for graduate students and the need to develop affordable housing for junior faculty members. The graduate student housing shortage was clearly the most urgent matter and was given priority. The subgroup reviewed a number of studies, gathered a great deal of data, and discussed the matter widely with those closely involved in the issue at MIT. The subgroup supported the progress made this year on the immediate goal of planning for the near-term construction of housing for several hundred graduate students. In order to avoid future emergencies, the subgroup urged that MIT develop a long-range plan which: a) would include the goal of providing MIT housing for at least 40-50% of our graduate students and a schedule for meeting that goal, and b) would couple the goal to the expected future size of graduate enrollments. The subgroup, with support from the entire FPC, submitted a report for discussion at the May Faculty Meeting.

At the urging of Associate Provost Jay Keyser, the FPC had several discussions on the issue of collegiality at MIT. The press of work can make it difficult for people to relate to one another, and (especially at the heart of an academic institution) to share the joys of understanding what our colleagues are thinking about and to have a sense of being part of a community. The wide-ranging discussions included issues of space layouts in departments, the impact of research policies and the efforts needed to raise research funds, lack of appropriate spaces (especially dining) for people to congregate, the difficulties of crossing departmental boundaries, etc. Independently of the FPC, the Associate Provost and others have moved forward with a number of initiatives, such as providing opportunities for Faculty across the Institute to get together for informal dinners and discussion, creating a Faculty "common room" or weekly lunch for faculty and guests, initiating an orientation for new Faculty members next year, etc.

The FPC had several discussions with Professor Frank Perkins on the size of graduate and research programs at MIT in relation to undergraduate enrollment. The ratio of graduate to undergraduate enrollments has grown from .85 to 1.1 over the past seven years, which raises some fundamental questions about the appropriate balance and whether the changes are in the direction in which the Institute wants to move. Overall, the time spent on raising research money, supervising graduate students, and managing a growing research enterprise is having an impact on undergraduate education (with respect to advising, participation in seminars and living groups, etc.) in ways that need to be understood better and addressed. We also need to understand the forces that drive graduate enrollment, especially in the face of evidence that Faculty members are already seriously over-worked. There are dramatic differences in style and patterns of change among the various departments. Dean Perkins will return to the FPC with some policy recommendations that are expected to emerge from the various studies he is undertaking.

Among other matters discussed by the FPC during the year were: a) the "Departmental Guidelines Relating to Academic Honesty", b) ways MIT can help as an educational institution to address apartheid (e.g., provision of scholarships for nonwhite students to attend college in South Africa and of fellowships for graduate students to study at MIT) and the motion that was presented at the December Faculty meeting on divestment and related follow up, c) the progress being made by the study group examining the effects of Project Athena, d) the Institute Colloquium, e) the proposal to establish a practical experience program at MIT, f) interim report from the Committee on MIT's Military Involvement (particularly the issue of whether MIT's research effort is unduly influenced by the concerns of the military), g) proposals from the Equal Opportunity Committee to increase the number of minority Faculty at MIT, h) faculty involvement in the Campaign and benefits of the Campaign to Faculty members, i) Interim Report of the Faculty Technology Transfer Committee, j) Report from the Committee on the Writing Requirement (particularly alternative strategies for dealing with concerns about Phase II) that was subsequently discussed at Faculty Meeting, k) broadening undergraduates' views and experience with community service while at MIT, and l) the Faculty Motion to extend CUAFA's authority to impose enrollment restrictions under certain circumstances.

The Ad Hoc Catalogue Committee, which has operational responsibility for the catalogue on behalf of the FPC, implemented the modifications required by the changes in the structure of the undergraduate program degree requirements approved by the Faculty in May 1985.

#### Committee on the Undergraduate Program

The CUP's charge is to concentrate most of its attention on longer-term issues relating to the nature and quality of the undergraduate academic program and the overall undergraduate experience. To make this possible, other Faculty committees are sharing the responsibility to address specific short-term academic concerns that need attention. A major goal for this year has been to begin the Institute-wide efforts needed to achieve a common understanding of undergraduate education at MIT -- what MIT is doing well and not as well, and what MIT should be doing in the light of society's needs and MIT's particular strengths and limitations.

Much of the CUP's fall term agenda -- through presentations/discussions by various CUP members and guests, as well as a great deal of background reading -- focused on preparation for two days of intensive meetings in January. These meetings were aimed at reaching, as a group, some agreement on the fundamental objectives and characteristics of an MIT undergraduate education (including identification of areas where there is significant disagreement) and on significant problem areas that constitute the future agenda of CUP.

Out of the January meetings emerged the beginnings of two major, but related, directions:

First, a preliminary statement was prepared of some assumptions and principles about the nature, character, and priority of MIT's undergraduate education around which the CUP had begun to coalesce. A revised version was sent to the Faculty in March. Attention was given to learning styles and formats, the priority of undergraduate teaching and advising, and the role of General Institute Requirements in an undergraduate degree program. The purpose in distributing the report was to begin a process of communication and iteration with members of the MIT academic community -- toward the goal of developing a more broadly shared Institute-wide consensus on these issues.

Second, a set of agenda issues and a tentative plan for moving forward on them emerged in the form of a working document, which continued to be refined during the term. Some of the most important problem areas to address, summarized in broad terms, are the following:

Nature and Character of MIT's Undergraduate Education. 1) The need to articulate: a concept of General Education as definition for the General Institute Requirements -- responsibility for which is shared by all Faculty, across all Schools; the appropriate balance and relationship between general education and the professional specialization components to achieve a coherent, broad education; the nature and rationale of the broader context for the undergraduate curriculum. 2) Assessing the kind of Institute-wide oversight and coordination (if any) needed for the General Institute Requirements and the freshman year.

Learning Styles and Formats for the Curriculum. 1) Encouraging more opportunities for one-on-one student/faculty encounters, and fostering a student orientation toward "making MIT your own." 2) Exploring new advising initiatives and the question of accountability for advisors. 3) Exploring questions about pedagogy and learning styles and how students learn best, e.g., making the undergraduate program student-centered rather than content-centered, developing students' own educational goals/values, and allowing for diversity among students in patterns of adaptation and learning style. 4) Ensuring that the impact of Project Athena on the nature and character of undergraduate education is adequately explored. 5) Determining how IAP can become more educationally rich and useful for our students. 6) Supporting efforts to strengthen a student culture centered around ideas, growth, and vision that interacts positively with the educational program. 7) Addressing the tone set by the freshman year in establishing students' approaches to MIT (R/O, freshman Pass/Fail, appropriateness of professional subjects, etc.) 8) Encouraging the perspective, through experiences in every subject offered at MIT, that writing and the written construction of arguments are essential tools in the process of conceptualization and learning.

Relative Priority of Undergraduate Education Amongst Other Faculty Commitments. 1) Examining leverage points for improving and rewarding good teaching, curriculum development efforts, dedicated advising, and other group and one-on-one interactions with students. 2) Exploring the necessity of intervening in the ratcheting research volume/graduate student/postdoctoral research spiral by policy directions.

While the discussions of shared assumptions and long-term agenda have been under way, the CUP has also been at the crossroads of discussions that have been initiated this year in four School and Institute committees to review various aspects of undergraduate education at MIT. The Committee on the Humanities, Arts, and Social Sciences Requirement is developing a proposal for a new HASS Requirement, with particular emphasis on the Humanities Distribution component. The School of Science Education Committee is looking at the required science core subjects (assessing the quality of teaching whether they provide a coherent basic education in the sciences), and reviewing the Science Distribution and Laboratory Requirements. The Commission on Engineering Undergraduate Education is conducting a comprehensive review of MIT's undergraduate engineering program, including the engineering curricula and those aspects of the Institute's core and of the Institute's environment that influence engineering education. The Committee to Design an Integrative Curriculum in the Liberal Arts has proposed an integrative program that establishes dual competency in a technical discipline (science or engineering) and a humanities, arts, or social science discipline.

The chairs of the first three committees sit on CUP as members appointed by the Dean for Undergraduate Education. During the year, the various review committees have made periodic reports to CUP, which have been invaluable in sharing ideas, as well as identifying and addressing differences in points of view and directions on various issues. The CUP has provided guidance to these committees as it reviews the recommendations for change in the academic program that are emerging from the review process.

A major priority of the CUP in the next 12 months is to bring to closure this review process. A design team is being established by Dean Friedlaender to develop a plan to move forward the recommendations from the Committee to Design an Integrative Curriculum in the Liberal Arts. A CUP subgroup will be working over the summer to take a first cut at reconciling the results to date of the deliberations of the HASS, Science, and Engineering review committees. The specific objectives are: 1) to develop reformulated General Institute Requirements where there is consensus, and to identify outstanding issues yet to be worked through, and 2) to develop a strategy and process for bringing the community closer to the work of the various review committees and for broadly engaging the faculty during the fall and winter of 1986-87, preparatory to faculty action as needed.

We are encouraged by the strong efforts of many people during the past year and, over the next several years, significant changes in undergraduate education are expected through support and encouragement of educational experimentation, curriculum development, and instructional innovation.

## Other Faculty Committee Reports

Chairs of the Faculty committees have submitted summaries of the major agenda items addressed during the past year, excerpted as follows:

Most of the busy schedule of the Committee on Academic Performance (CAP) was spent reviewing the academic performance of all MIT undergraduates with the able and devoted assistance of our Staff Assistant, Steve Patterson, and with the willing cooperation of the departmental undergraduate officers. The most time-consuming part of this committee function is dealing with those students whose performance requires CAP action, such as academic warning, required withdrawal, or readmission after a withdrawal. In this, CAP gets a great deal of assistance from students' advisors. Fortunately, the number of students involved is not terribly large, but the process uses a disproportionate amount of committee time. At the end of the spring semester 1985, 171 students were placed on warning and 56 were asked to withdraw. At the end of the fall semester of 1985, 205 students were placed on warning and 26 were asked to withdraw.

In addition, CAP dealt with many petitions from undergraduates for variances to the MIT rules. In general, CAP agreed to those variances that made good educational sense and that were based on reasonable circumstances; CAP also denied many petitions.

On the more positive side, CAP sent reminders in good time to students who had accumulated incompletes and who would clearly need credit for the subjects for graduation, urging them to complete these incompletes. This new procedure, which was started a year ago, has been quite successful in greatly reducing the number of degree candidates who had to "scramble" to finish some old "I" grades in order to have the requisite number of units for graduation.

CAP also instituted and publicized a more rigorous view of the rule that allows the committee to recommend a degree for a student who has "one deficiency in the final term" under certain circumstances. CAP now will not recommend a "single deficiency" degree, if that deficiency is in a subject that is an Institute Requirement.

Twice during this last year, CAP has considered a suggestion that the committee recommend to the Faculty the policy of a higher minimum standard of academic performance before a degree is granted. Such a standard might be similar to the one in use at Harvard. The rationale for seeking a higher minimum academic standard is based on the realization that the D grade indicates serious insufficiencies in the student's knowledge. If a candidate had accumulated a record in his or her professional subjects consisting mostly of Ds and Cs, it might not be appropriate to award an MIT degree with all that this implies. However, CAP did not agree to make such a recommendation for a variety of reasons. The most cogent reason was based on the definition and use of the D grade as "minimally acceptable," though indicating certain handicaps. The issue of a higher minimum standard remains unresolved.

The Committee on Curricula (COC) held 12 meetings during the 1985-1986 academic year. Most of the time was spent considering proposals and petitions, although several broader issues also were discussed. The Committee reviewed the revisions of each departmental program made in accordance with the new Faculty Regulations on the structure of the undergraduate program.

The COC acted on Faculty proposals for new subjects (including undergraduate seminars) and for changes in content, units, title, or description of existing subjects. The Committee heard proposals by the Experimental Study Group (ESG) and by the Women's Studies Program for independent-study subjects and decided, after considerable discussion, to approve both on an experimental basis, subject to review next year.

The student petitions were primarily requests for substitution of subjects satisfying Institute requirements. A few petitions for permission to work toward a second S.B. degree were received. The Committee decided to adopt the policy of not approving such petitions until a student has completed his/her sophomore year, so that two terms of letter grades would be available, although in special cases petitions from second-term sophomores would be considered.

The elimination of required labs from 8.01-8.02 led to broader discussions of the Institute Laboratory Requirement, the possible interdepartmental "Freshman Lab," and small-scale lab "experiments" such as carried out in 8.012 and ESG. Consideration of student petitions for Institute Lab substitutions (particularly in the area of social science and "software" labs) led to the question of whether we need new guidelines for this requirement. The whole Laboratory issue was seen as too large to be addressed by COC in any meaningful way in view of the Committee's other duties; we felt that it should be taken up by a specially designated faculty committee.



The COC raised the question with the Physics Department as to whether there should be more options in introductory physics, given the range of abilities and preparation of entering students. It is our understanding that this issue is being explored by the department. The COC intends to follow up on this matter in the fall.

An issue that had been raised with the Biology Department by the COC in the spring of 1985 regarding the consequences of 7.01 being offered only during the spring term was discussed again this past year. The Committee felt that this subject should really be given both terms, as are introductory subjects in most other departments. If this were impossible, arguments were put forth for giving 7.01 in the fall rather than in the spring. Discussions of this matter were held with several members of the Biology Department and with Dean Brown; as yet, the problem has not been resolved. We expect to take this matter up again early in the fall.

In addition to its regular responsibilities during the past year, the Committee on Discipline (COD) undertook a thorough revision of its published internal rules and regulations under which it operates. The purpose of the revision was to state as clearly as possible the rights and responsibilities of all parties involved in cases brought to the attention of the Committee. The revised rules and regulations have been reviewed by legal counsel and are ready for use in future cases.

The Committee on Student Affairs was among the bodies that helped accelerate MIT's plans for additional graduate student housing. CSA also: suggested an activity focused on promoting student opportunities for public service to be located in the Office of the Associate Provost for Educational Programs and Policy; participated in planning experimental programs for improving the first-year advisory system; and prepared an agenda of ROTC issues for discussion during the coming year.

During the past year, the Committee on Undergraduate Admissions and Financial Aid 1) concentrated on marketing strategies and contributed to the development of a new brochure for recruitment; 2) participated in and approved a modified selection process, to be implemented beginning the fall of '86; 3) decided not to impose restrictions with respect to the choice of major on the freshman class entering in the fall of '87, but requested and received faculty approval to extend the authority to impose restrictions for two additional years; and 4) initiated a new exploratory project of reading freshman applications to learn more about the patterns of choice of major in the undergraduate population.

During the year, the Committee on the Writing Requirement reported to the Faculty on Phase One and continued its work in implementing Phase Two. Our Phase One Report recommended narrowing the Marginal Pass category (used in judging essays and papers) to encourage students to sharpen their writing skills before attempting Phase Two. The concentration of effort has been on Phase Two. In anticipation of the Faculty's assuming primary responsibility for Phase Two, we have developed a "Strategic Plan" for overall implementation of the Requirement. The plan reflects our concern for uniform standards in judging writing -- a concern that stimulated a series of meetings with departments to discuss this issue. The Class of 1987 must have completed both phases of the Requirement within the next year. We are working with the Faculty, the Committee on Academic Performance, and the Registrar to smooth that process and have devised a number of measures to alert both students and their advisors to students' progress in satisfying the Requirement.

The Committee on Faculty-Administration met only once. At that time, we approved a statement dealing with "Faculty Misconduct or Performance Below Standards" and "Termination of Tenure" for MIT's Policies and Procedures manual. The committee does not have a definite agenda but rather reacts to requests when there are issues involving relationships between administration and faculty that deserve special attention.

The Industrial Liaison Committee has spent most of this past academic year trying to find new ways of making the Industrial Liaison Program even more responsive to the needs of faculty and to the needs of member companies. A number of strategies emerged. These will be tested in the next year or two. Overall, the Industrial Liaison Program appears to be operating in a highly effective fashion.

During the past academic year, the principal issues covered by the Committee on the Library System included: review of the activities of the Libraries for the previous year; priorities for the Libraries for FY86 and FY87; library hours, especially access to the Science Library, a major concern of the Department of Chemistry; review and approval of the allocation of the acquisitions budget for FY86; circulation policies, including a major review and revision of those related to the suspension of privileges (this issue evolving out of the need to redefine a number of policies in light of the new automated system); and circulation and fine policies in general. On May 29, the Committee hosted a meeting for faculty and students with the Corporation Visiting Committee for the Libraries.

The Committee on Outside Professional Activities examines confidential matters pertaining to faculty conflict of interest and to advising faculty and administrative staff in this regard. The Committee met once in 1985-86 in response to a specific request.

The Committee on Nominations presented its slate of elected members of the faculty committees, including the Chair-elect of the Faculty, at the April Faculty Meeting, and filled vacancies in the elected membership as needed during the year.

Professor Mildred Dresselhaus was named the Killian Faculty Achievement Award Lecturer for 1986-87, and Professor Jeffrey Lang was the recipient of the Edgerton Faculty Achievement Award for 1986-87.

The Ad Hoc Committee on MIT's Military Involvement, after gathering a great deal of information and conducting some surveys of its own, submitted its report for discussion at the May Faculty Meeting. The Faculty voted to continue its review of the impact of the shift of government support for scientific research and education from the civilian to the military sector in the fall, requesting the President to appoint a new committee to further the study.

Sincere appreciation is extended to the following faculty members for their special contributions and service as chairs of the Standing and Special Faculty Committees during the past year: Vernon Ingram (Academic Performance), Margaret MacVicar (Undergraduate Program), June Matthews (Curricula), Elias Gyftopoulos (Discipline), Arnolfo Hax (Faculty-Administration), Frank Perkins (Graduate School Policy), Lawrence Susskind (Industrial Liaison), Henry Marcus (Library System), Felix Villars (Nominations), Robert Alberty (Outside Professional Activities), Alvin Drake (Student Affairs), Kenneth Manning (Undergraduate Admissions and Financial Aid), Kenneth Hoffman (Writing Requirement), William Porter (Killian Award Selection Committee), Thomas Kochan (Edgerton Award Selection Committee), and Carl Kaysen (Ad Hoc Committee on MIT's Military Involvement).

MARY C. POTTER  
DAVID S. WILEY

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# School of Architecture and Planning

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Throughout the School effort has been concentrated this past year on advancing and improving the underlying professional programs as well as our major new initiatives in real estate and in media arts and sciences. Important progress was also made on such continuing needs as fundraising and improvement of facilities.

## Facilities

In the fall the Wiesner Building was formerly dedicated; and in the summer of 1986 a contract was let for the completion of its experimental media facility. In the spring the School opened its new exhibition space on the fourth floor of building 7 as part of the School's long range plans for improved communal facilities at the center to bring together students and staff and faculty now dispersed in three campus locations. Finally, in addressing the School's space needs, we were able to crystalize three sites as options for the upgrading of Rotch Library and secure an Institute commitment for an early decision between these sites as well as a first priority capital project status for Rotch Library.

The School's Computer Resource Laboratory and Project Athena computer clusters completed its move into the fifth floor of building 9. A very effective modification has been made to the space to create a sophisticated teaching space with rear projection of computer images.

## Administration

The Dean's Office expanded its administrative capacity with the promotion of Barbara Lister-James to Assistant Dean for Administration. Deborah Cohen has recently been appointed as Assistant Dean for Resource Development to direct a vigorous fundraising program in concert with the forthcoming Institute campaign. The nature of the School's preliminary fundraising goals include endowment for student financial aid and faculty chairs as well as expendable funds for space improvements. In scale the needs total about \$1000 million. Consistent with a scaling down of these needs to campaign target levels the School's endowment target is \$21 million, as part of an Institute campaign target currently totalling \$550m.

## Visiting Committee

The School's Visiting Committee met in October and carried out their review as three subcommittees: Architecture, Media Arts and Sciences, and Urban Studies and Planning. The Architecture Subcommittee returned in December for additional time to assess the range and complexity of departmental issues. In regard to the professional program in Architecture the Committee urged more effort in defining and communicating its purposes and in reciprocal connections to the world of American practice. Overall the Committee reported being impressed with the School's substantial progress in curriculum innovation, research growth, and the development of improved physical facilities.

## Activities

Particularly evident over the year was a resurgence of student energy and interest, supported in part by the better climate for employment and modest improvements in student financial aid. Two student sponsored events attracted national attention -- a week-long symposium and design charrette in January 1986 entitled "An Architecture of Substance" and a conference on the intellectual and cultural effects of post-modernism in April 1986.

The journal of the American Institute of Architecture prepared a profile of the Department of Architecture to be published in August.

In May students and faculty alike joined with over 150 alumni/ae of the Department of Urban Studies and Planning to celebrate the fiftieth anniversary of the award first city planning degrees and the founding of the second oldest planning department in the United States. A new School lecture series was well-received and will be repeated next year. The series was entitled 'Models and Mirrors' and lectures were presented by Michael Sorkin, Spiro Kostof, Richard Sennett, David Gebhard, and Anne Whiston Spirn.

The School's presence in the larger community has been distinguished by its public appointments and contributions. In that tradition John de Monchaux recently accepted an appointment by the Mayor as the Chairperson of a newly established Boston Civic Design Commission. Following up the School's leadership of earlier city-wide conferences, the School this year assumed responsibility for directing the first

Governor's Design Awards Program. Professor Lang Keyes and Tunney Lee returned to the School after a distinguished period of service in the government of the Commonwealth of Massachusetts.

The Computer Resource Lab, under the direction of Professor Joe Ferreira consolidated its operations and extended the amount and complexity of support it offers to students and faculty in the School. Over 200 students were enrolled in classes using machines and software in the CRL provided largely through Project Athena. Plans are in place to further develop the CRL and budget support for a full time lab manager was secured from the Institute.

In an effort to address educational and resource issues that lie across the School as a whole two Schoolwide faculty committees met during the year. The first of these, chaired by Professor Leon Grossier, was charged with an examination of possible new directions in the School's undergraduate offerings. This review was coordinated with the Institute wide reviews of undergraduate education, including in particular the deliberations of the 'Maier' Committee. This committee's report established promising directions for further work, which will concentrate on new and reconfigured programs to attract undergraduate majors to the School. The Media Arts and Sciences program received curriculum development money to undertake a 1986 summer study to address their special role in undergraduate education.

The second faculty committee, chaired by Professor Ralph Gakenheimer, was asked to look at the subjects and continuing education programs offered in both departments that bear on issues and needs of developing or non-western countries. The committee has met throughout the year in an effort to achieve greater effectiveness and coordination of developing areas activities across the School as a whole. It has put forward a brief interim report and will continue to meet through the coming year.

Although research levels for the past year showed some improvement, we continue to need more and more predictable funding to support students, particularly in such areas as the S.M.Arch.S. and planning Ph.D. programs. Major funds, both in terms of growth and research are also needed to continue a vital Computer Resource Laboratory beyond the end of Project Athena support.

#### Community Composition

The School continued to experience a decline in minority student applications. In contrast, the strong presence of women in our student body continues. The Department of Urban Studies and Planning received funds to improve minority recruitment efforts. One minority faculty was hired in the Department of Urban Studies and Planning, but overall the School did not meet its hiring improvement aspirations. Nor was the Institute able to support our second request for target of opportunity funds to recruit a senior woman faculty member. School Council decided to renew its efforts at improving the diversity of the faculty recruitment pool and to explore new approaches to improving the climate for women and minorities. Responsibility for the regular oversight of the Institute's affirmative action program within the School was transferred during the year from Academic Council to School Council for a trial three year period.

#### Issues

More generally the School continues to face the dilemma of how to shed fields, in response to the recent budget-driven faculty contraction and the current faculty disposition and seniority. Notwithstanding these factors, we continue to undertake such new initiatives as the real estate program which, given constraints on faculty size, lead us to rely upon non-tenure track people and to the consequent discontinuity over time. These issues will receive new attention in the coming year.

Of increasing concern is the School Council's perception of a level of disaffection on the part of senior faculty, which is ascribed to four major factors:

- .salary discrepancies with others across the Institute and the appearance of potentially divisive differentials within the School;
- .a shift in focus of professional life away from the School, which leads to disruptive patterns of leave-seeking and interruptions in course offerings;
- .lack of consistent faculty responsibility for research support for graduate students in many parts of the School; and
- .uneven quality and timing of response and support that different parts of the School receive from different parts of the Institute's central services. These are important questions for the School which will need to be addressed in the coming year.

The structure for responsibilities across the School needs work. Most immediately we need to put in place the senior faculty committee for the Master of Science in Real Estate Development degree. The governance of Media Arts and Sciences remains an issue to be addressed during the coming year.

JOHN de MONCHAUX

STUDENT ENROLLMENT AND COMPOSITION 1985-86

<u>Department of Architecture</u>	<u>Total</u>	<u>Women</u>	<u>Minority</u>	<u>International</u>
Undergraduate	75	29	11	10
M.Arch.	81	29	4	14
S.M.Arch.S.+	69	20	2	48
S.M.Vis.S./S.M. (unspecif.)	45	22	0	2
Ph.D. (resident)	30	7	1	10
Total Graduate Resident	300	107	18	84
S.M. Real Estate Devel.++*	19	3	0	0
Ph.D. (non-resident)	11	4	0	2
Graduate Specials**	7	5	1	2
Architecture Totals	337	119	19	88
<hr/>				
<u>Department of Urban Studies and Planning</u>				
Undergraduate	4	2	0	0
M.C.P.	85	39	12	26
M.S.R.E.D.	37	10	2	2
Joint M.C.P./M.Arch.	18	6	1	10
Ph.D. (resident)	53	24	3	26
Total Graduate Resident	197	81	18	64
Ph.D. (non-resident)	34	18	3	16
Special Students **		8		
SPURS***	20	4	0	19
CFP***	9		9	0
DUSP Totals	260	111	30	99
<hr/>				
<u>SCHOOL TOTALS</u>				
Undergraduate	79	31	11	10
Graduate	463	179	28	156
Special Students	55	20	10	21
TOTAL ENROLLMENT	597	230	49	187

\* Only includes those students registered in Course IV

\*\* Non-degree

\*\*\* Special non-degree programs in DUSP; SPURS; and CFP

+ Five of these students are also working toward the MCP degree

++ Two of these students are also working on their M.Arch. degrees

## FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1984-1986

	1984-85				1985-1986			
	Total	*E.F.T.	Women	Minority	Total	*E.F.T.	Women	Minority
<u>Architecture</u>								
Faculty	34	31.5	3	--	35	33.75	4	--
Other Academic Staff	38	17.5	8	--	39	30	3	1
Research Staff	13	10	1	--	22	16.25	6	1
Without Pay	4	4	1	--	19	15	1	--
<hr/>								
<u>Department of Urban Studies and Planning</u>								
Faculty	26	24	3	3	26	24	4	4
Other Academic Staff	10	5.25	3	1	19	7.66	3	1
Research Staff	--	--	--	--	--	--	--	--
Without Pay	18	--	9	6	21	--	9	3
<hr/>								
<u>Laboratory of Architecture and Planning</u>								
Faculty	--	--	--	--	--	--	--	--
Other Academic Staff	2	2	--	--	2	1.75	--	--
Research Staff	13	5	8	--	11	9.05	7	--
Without Pay	13	9	4	--	14	4.35	3	--
<hr/>								
<u>SCHOOL TOTALS</u>								
Faculty	60	55.5	6	3	61	57.75	8	4
Other Academic Staff	50	24.75	11	1	60	39.41	6	2
Research Staff	26	15	9	--	33	25.30	13	1
Without Pay	35	13	14	6	54	19.35	13	3

\*Effective Full Time

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## Department of Architecture

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This academic year has seen continued progress toward some key objectives identified in the Department's five-year plan and in curriculum studies of the past four years from which it is in part derived. Central among these objectives are to increase diversity in theoretical position and experience to inform architectural design studio teaching; to continue development of a research tradition in the Department; to correct the imbalance of faculty age and the serious lack of younger faculty; to increase the engagement of academic programs with issues of current practice; and to maximize faculty and budget resources by effective collaboration among programs.

Most notable among accomplishments this year is the conclusion of four major faculty searches, resulting in five hirings (an increase in junior faculty of 13 percent) and two pending senior appointments.

The Master of Architecture (MArch) program has been the focus of considerable attention. One key search was begun 18 months ago to identify two new teachers of architectural design with records of combined achievement in teaching and architectural practice who would bring appropriate diversity to studio teaching. The search committee, chaired by Professors Imre Halasz and Robert Slattery, considered approximately 150 applications and 100-150 additional nominations for a tenured and a tenure-track position. First choice for the tenure-track position from a field of excellent candidates, William Hubbard from UCLA, will join the design faculty as an Assistant Professor in fall 1986. The committee's nominee for the tenured position will be appointed to the faculty in fall 1987 pending Institute approval.

A second outcome of the committee's comprehensive review was a proposal for a distinguished visiting critics program, to be mounted annually, and a list of visitors to be invited. A first set of three prominent architects, among them Gottfried Böhm, winner of the 1986 Pritzker Prize in Architecture, has been scheduled to teach the advanced design studio in fall 1986.

An important new formulation of the Building Technology group has been developed which promises to strengthen teaching and research in the area through collaboration with the Departments of Civil and Mechanical Engineering. A search for a senior faculty member begun in the last academic year was re-directed this year on advice from a senior consultant study group convened at Endicott House in October 1985. New opportunities in research, opened especially through development efforts by the Laboratory for Architecture and Planning, suggested that a faculty member with strong traditional research skills and background be sought and the focus of part of the Building Technology group work be on research and education which will contribute to the next generation of technological practice in buildings. A proposal is now under consideration for the appointment, jointly with Mechanical Engineering, of a tenured professor in building technology. A proposed interdisciplinary program would feature active involvement in research at the forefront of technology grounded in understanding of both basic engineering disciplines and the overall building environment that the specific technology will be applied to. Such a program, centered within a department of architecture, would be virtually unique in the country and offers a rich potential opportunity for innovative work.

A third area impacted by a Department search is the School of Architecture and Planning Computer Resource Laboratory (CRL), which has continued this year to operate successfully as an element of the Institute's Project Athena. The addition in the fall of two junior faculty members, Assistant Professor Frank Miller and James Anderson as Lecturer, from the Architecture side will amplify subject offerings in computer-aided design for undergraduate and graduate students in both the professional and post-professional degree programs and broaden research efforts at the CRL. Prospects for continued operation and growth of the CRL after the withdrawal of Project Athena should be substantially reinforced by their activities.

A fourth Department search, in the area of History, Theory and Criticism (HTC) of Art and Architecture, has been concluded in the recommendation to appoint two junior faculty members--one Assistant Professor of the History of Architecture, one Lecturer part-time. These appointments, which become effective in fall 1987, stabilize the teaching complement of the group, which has undergone some major change due to the resignations in the last four years of two of its senior faculty.

As has been noted in past years, two perennial areas of need remain to be addressed: financial support for our students and space for the Department and School. Real improvement in student morale was noted this year, directly related to increased amounts of financial aid available for MArch and SMArchS students and the Department's new policy for distribution of aid to cap student debt. Additional funding will need to be sought for coming years when the extra scholarship funding granted us by the Institute expires. It is hoped that the Institute's general campaign and School fundraising efforts will focus in part on this need.

Improvement of School space continued to be a preoccupation, with continued attention focussed on feasibility studies for the expansion of the Rotch Library. Plans for adaptation of Building N52 for teaching and office space for the Laboratory for Architecture and Planning and elements of the Department's SMArchS program proceeded slowly, with completion of some elements and occupancy expected in fall 1986. A very positive improvement was the construction and dedication this spring of a large and attractive exhibit space on the fourth floor of Building 7. The gallery and adjacent coffee house, opened two years ago, represent an encouraging start for the projected School Center.

The Department was very pleased to receive a generous gift from the family and friends of Arthur H. Schein (BArch '51) to endow an annual lecture and exhibition series in his memory. Renzo Piano, architect of many important projects in the US and Europe including the Beaubourg in Paris, gave the first Schein lecture in November 1985. A large audience from MIT and the Boston architectural community attended Piano's talk and the opening of an exhibition of his work titled "Piece by Piece" in the Compton Gallery. A second Arthur H. Schein lecture in April was given by Italian architect Giancarlo De Carlo, Director of the International Laboratory for Architecture and Urban Design, Milan.

Finally, a highlight of the Department's year was a week-long symposium and design charette called "An Architecture of Substance," held January 27 to February 2, 1986. The event was conceived of and organized by six graduate students, led by Paul Lukez (MArch '85) and Mary Meagher (MArch '86) and supported by grants from the Department, Jordan Gruzen (BArch '57), Peter Samton (BArch '57), I.M. Pei (BArch '40), Norman Leventhal ('38), Symmes Maini & McKee, Cambridge Seven, and the MIT Council for the Arts. Intended to be an event "outside...traditional architectural settings," it brought together nearly 60 students from schools in the US, Tokyo, Zurich and Stockholm at MIT to hear and work with teachers and architects who made up the symposium panel and led workshops treating the design of an "information arts center." Contributing teachers and practitioners included Kurt Forster, Zaha Hadid, Eric Moss, Peter Prangnell, Wolfgang Prix, John Whiteman and Fumihiko Maki, who gave the symposium concluding lecture.

#### PROGRAMS

In 1985-86 there were 292 regular students in the Department's five degree programs: PhD (30), SMArchS (65), SMVisS (45), MArch (80), and BSAD (72). This represents a four percent increase in student numbers over last year.

The MArch and SMArchS programs remained at approximately the same numbers as in past years; PhD students increased by the admission of 10 candidates in Media Technology through the Media Laboratory; a new concentration opened in SMArchS in Design for Islamic Countries accepted nine new students.

The number of undergraduates enrolled in Course IV remained approximately the same as last year. There were 57 in the pre-professional architecture concentration, 10 in the concentration in Media Technology, and five in miscellaneous concentrations.

Of the total student population, 28 percent were women, three percent were minority, and 26 percent were foreign students. There were 521 applications for admission to Department graduate programs for fall 1986, which is approximately the same as in the previous year. PhD in HTC showed a small increase, PhD in Media Technology a small decrease, and all the other programs' application numbers remained stable.

#### Master of Architecture (MArch)

There were 214 applications for admission to the professional (MArch) program, a slight increase over the number received in the previous year. Admission was offered to 55 students total (11 of these MIT undergraduates) and 42 first-round choices (76 percent) accepted (nine MIT undergraduates). In marked contrast to last year, the rate of acceptance of admission was so high that no waiting list candidates could be admitted. A real and welcome difference from the past several years is the substantially larger number of BSAD graduates who have elected to continue their professional training in the MIT graduate MArch program.

The MArch/BSAD committee continued active management of the professional program. Chaired by Department Head, Professor John Myer, the committee met weekly to discuss and make policy on issues ranging from the practical (studio upkeep, equipment acquisition, hiring of student employees) to the theoretical (studies of Level I teaching, thesis and thesis preparation subjects, required subjects for the MArch degree, and undergraduate/graduate relations in the professional program). Committee members from the faculty were Professors Fernando Domeyko and William Porter; students members were Hassan Abousseda (MArch), Julie Campbell (MArch), and Oren Helbock (BSAD).

A number of new "platform" subjects were proposed for the professional (MArch) curriculum by a study group active in 1984-85. Two of these subjects, 4.296 Professional Practice Seminar: The Management of the Design Process and 4.698 Criticism of Contemporary Architecture, were offered in spring 1986. Two additional platform subjects in Environmental Technology and Visual Training for Architects are being prepared for the spring term, 1987.



There were a great many visitors this year who gave lectures sponsored by several Department groups. As noted above, the first Arthur H. Schein Memorial Lecture brought Renzo Piano and Giancarlo De Carlo to MIT. In March, the Department hosted a week-long visit from Portuguese architect, Alvaro Siza, who participated in architectural studios and lectured in conjunction with the first American exhibit of his work in the List Visual Arts Center. The student lecture series offered a slate of speakers from Europe and the United States, including J.B. Jackson, Jacques Blömer, Michael Photiades, and Tobias Faber. Lecturers invited by the design faculty included teacher-practitioners David C.S. Polk, from the University of Pennsylvania, Panos Koulermos--University of Southern California, and Erich Schneider-Wessling from Cologne, Germany.

Awards to students in the professional program were as follows: the Francis Ward Chandler Prize for achievement in architectural design to March students Catherine Verhulst, Robert Maulden, Karen Swett, Margaret Lew, and Wendy Frontiero; the William Everett Chamberlain Prize (given for the first time this year to graduating BSAD students) to Keith Turner and Chiong Chiong Lin; the Alpha Rho Chi Medal, for leadership and promise of professional merit, to Mary Meagher and Gail Sullivan; the AIA Certificate of Merit, for the second-ranked March student, to Richard Berg; and the AIA Medal, for the top-ranking graduate student in the Department, to Margaret Wohl.

Other honors and awards to our graduate students from outside MIT: first prize in the Harvard-MIT Joint Sketch Problem, April 1986, was awarded to Karen Swett (March '86), and Peter Batchelor (March '87) was selected as one of five semi-finalists in the Skidmore, Owings and Merrill Foundation Traveling Fellowship competition.

#### Master of Science in Architecture Studies (SMArchS)

The number of applications to this program in 1985 was 147, higher than in the past four years, and 37 students enrolled in the fall of 1985 (as opposed to 22 the previous year). Design for Islamic Cultures--the newest area of study in the SMArchS program--enrolled its first students (9) this year. The SMArchS program was directed by Professor Julian Beinart.

The program maintained a wide variety of research projects in 1985-86. Professor John Habraken was awarded an NSF grant to develop "design games" as a means of enabling various actors to play systematic roles in the design process. Professor Habeel Hamdi and Research Associate Reinhard Goethert continued their work, with the National Housing Development Authority of Sri Lanka and UNICEF, in local builder training and slum upgrading. Professor Edward Robbins also participated and is currently editing a book on the work. Dennis Frenchman, and his spring 1986 architectural design studio, undertook a successful study of the future growth of Lake Placid, New York. In the Design for Islamic Cultures area, work has begun on a comparative study of Islamic urban patterns. In the Building Technology group, Professor Eric Dluhosch began the first phase of a computer-based educational/design study for the International Masonry Institute and, with Professor Wacław Zalewski and Research Associate Charles Helliwell, continued an action improvement program for prefabricated factories in Egypt, under the auspices of MIT's Technology Development Center and Cairo University. Professor Ranko Bon is in the later stages of research for the IBM Corporation on building evaluation and expert system development; studying strategies for real property assessment for the Construction Engineering Research Laboratory of the US Corps of Engineers; and, with the MIT Laboratory for Architecture and Planning, has begun work on comparative studies of construction in the US and Japan.

A series of Special Interest Group on Urban Settlements (SIGUS) workshops were run on problems of housing and development with SMArchS and other students working with consultants from the World Bank, UNICEF, USAID, and officials from Mexico and Chile. Visiting lecturers to the Design for Islamic Cultures area included Charles Correa, Geoffrey Bawa, Leon Krier, Jacquelin Robertson, Hussein Afnan, and Kamran Diba. MIT faculty in this area also visited architecture and urban design schools in Tunis, Morocco, Jordan, Pakistan, Bangladesh, Singapore and Indonesia. The Environmental Design Group continued its series of forums with speakers including Peter Limos, contributing editor of Metropolis Magazine, Robert Campbell, from the Boston Globe, and David Clem, the Athenaeum Group.

Two SMArchS student received Institute awards this year. John Dale ('86) was awarded the Marvin Goody Prize for the best thesis in the building arts. The prize is awarded annually in memory of Marvin Goody, a former member of the Department faculty. The Tucker Voss Award, which honors annually one or more students who show particular promise in the field of building construction, was given to SMArchS Building Technology student, Kazunobu Minami.

#### Media Arts and Sciences (MAS)

Many of the teaching functions in the Media Arts and Sciences program are tightly coupled with the research activities of the rapidly growing Media Laboratory, and graduate students are therefore deployed across its many areas of specialty. Masters level candidates remained essentially constant in numbers at 37. Seven new masters candidates were admitted for fall 1986. Of them, about one-third came from design, arts or film backgrounds. The balance arrived more technically prepared to be part of research teams

from the onset. PhD enrollment in MAS increased from 14 to 17 during the year, approximately evenly split between the social sciences and computer sciences, with the exception of two candidates specializing in music research.

An ongoing search for faculty in MAS, opened in 1984, this spring yielded recommendations for three new appointments. One appointment was approved before the academic year ended--that of Ms. Edith Ackermann as Assistant Professor of Epistemology, to teach and work in learning research. Pending Institute approval Alex Pentland and Edward Adelson will join the Media Laboratory as Associate Professors in the next academic year.

The Media Arts and Sciences faculty of the Department has been working with colleagues from the Departments of Electrical Engineering, Humanities, Political Science, and Brain and Cognitive Sciences, to design a new PhD program, to redesign the Master of Science in Visual Studies (SMVisS) program, and to explore the feasibility of an undergraduate concentration. This year saw three initiatives: 1) the finalization of a new PhD area of concentration called Media Arts and Sciences; 2) the creation of a summer study group to report in the fall of 1986 to Dean de Monchaux and the Provost on the nature of a new discipline and its appropriateness to undergraduate teaching and/or concentration; and 3) the decision to use the Master of Science unspecified until such time as a masters program emerges at the overlap of undergraduate and PhD studies in Media Arts and Sciences. (Masters students in Environmental Art would continue to receive the SMVisS degree.)

#### PhD

PhD students totaled 41, 30 in residence and 11 non-resident, in the History, Theory and Criticism of Art and Architecture. There were 42 applications for admission made for seven places available in fall 1986. Professor Stanford Anderson chaired the PhD program in HTC.

A major event of this academic year was a conference titled "The Postmodern Condition: Architecture, Culture, Ideology," organized by PhD candidates Libero Andreotti, Marc Grignon, Michael Hays, Sergio Palleroni, Nasser Rabbat and Danilo Udovicki. The conference, held at MIT in May, brought together historians and theorists of architecture and art, philosophers and scholars of culture and the humanities. Among them were Benjamin Buchloh, Alan Colquhoun, Frederic Jameson, Rosalind Krauss and Edward Said. The principal aim of the conference was to analyze and evaluate the concept of postmodernism in architecture as a symptom of a more general ideological and historical condition, and to promote debate and discussion of the possibility of criticism in a postmodern condition.

The PhD Forum continued this year, bringing distinguished scholars who led seminars for the HTC group. Speakers were John Whiteman, from the Harvard Graduate School of Design, and Renata Holod, Department of Fine Arts, University of Pennsylvania, among others.

Some honors, awards and activities of HTC students include: a Fulbright Fellowship to Italy to Libero Andreotti; Mark Jarzombek received a fellowship at the J. Paul Getty Center for the History of Art and the Humanities. Hong-Bin Kang ('80) has been made architect-in-charge of the 1987 Olympics Master Plan for Seoul, Korea, with the firm of Woo and Williams. Peter Testa prepared the exhibit of the work of Alvaro Siza for MIT's List Gallery; August Sarnitz prepared an exhibit of the drawings of Otto Wagner for the Los Angeles County Museum in 1987. Among a number of academic positions given HTC students--Michael Hays was appointed in the Department of Architecture at Princeton, Mark Jarzombek was appointed Assistant Professor at the University of Texas/Austin, and Jay Chwining, Assistant Professor at Ball State University.

#### FACULTY

Visiting faculty in architectural design this academic year were Edward Cullinan, architect from London, and his partner, Mark Beedle, who co-taught a Level II-III design studio in the fall. Cullinan and Beedle also offered a very successful second subject--"Drawing from History--The History of Drawing," which focussed on "open form" architecture (1850's to Le Corbusier) in lectures and workshops in drawing and presentation techniques. Doris and Ralph Thut, architects from Munich, co-taught a Level II-III design studio, also in the fall. In the spring term, Tom Chastain (MARCH '82) and Renee Chow (MARCH '80) co-taught a Level I studio and Thomas Hubka, author and architect from Portland, Maine, directed a Level II-III studio. Leslie Kanes Weisman, Associate Dean of the School of Architecture, New Jersey Institute of Technology, offered a subject titled "Architecture and Planning in a Feminist Society" in spring 1986. Her visit was organized and sponsored by the Department's Women in Architecture group. Department graduates, Tom Hille (MARCH '82) and Judy Dayton Mitchell (MARCH '83) were appointed in the spring term--Hille to assist Professor Halasz in his Level II-III studio, Mitchell to teach the MARCH thesis preparation subject.

Professor Adolf Vogt, Emeritus Professor from the Federal Institute of Technology (ETH), Zurich, was Visiting Professor in the HTC section for the academic year. Meg Licht taught subjects in the fall term on Italian architecture of the 15th and 16th centuries and Buildings with Centralized Plans. PhD candidates Paul Bentel and Michael Hays were appointed in the spring term: Bentel taught American Landscapes,

Hays taught Criticism of Contemporary Architecture, a first formulation of a platform subject proposed in the March Curriculum Study Group report of 1985.

Professor Bon was named to the newly-created Macomber Career Development Chair in Building Technology. Professor Hamdi, holder of the Ford Career Development Chair in International Studies, was promoted to the rank of Associate Professor. Professor Harvey Bryan has resigned, effective the end of this academic year, and will accept appointment at Harvard. Professor Robert Preusser retired at the end of the last academic year as Professor of Visual Design. He had been on the Architecture faculty since 1954 and had, in recent years, also served as Director of Education of the Center for Advanced Visual Studies.

Professor David Friedman was on leave in the fall term 1985, as a fellow at the Institute for Advanced Study, Princeton University, where he completed work on a book. Professor Stanford Anderson took partial sabbatical leave in the spring term. Professor Yasser Tabbaa, Aga Khan Assistant Professor of the History of Islamic Architecture, also took leave in the spring and was replaced by James Dickie from the Muslim Institute in London.

In the Media Laboratory, Professor Andrew Lippman received the Graduate Student Council Teaching Award for the Department given by the Graduate Student Council. Professor David Zeltzer was awarded the NEC Career Development Chair for Computers and Communications, held previously by Professor Lippman. Professor Tod Machover joined the faculty in fall 1985 from the Institut de Recherche et Coordination Acoustique/Musique, Paris. Professor Stephen Benton was granted permanent tenure in an early review, and will be full-time in the Laboratory beginning in the fall 1986.

Visitors to the Media Lab included Associate Professor Jeffrey Kulick, from Queens College in Canada, who worked in holography; Stewart Brand, of Whole Earth Catalogue fame, who worked with the "computers and entertainment" group; Marie Cosindas, who taught photography; and German filmmaker, Klaus Wildenhahn, who presented a series of screenings co-sponsored by the Goethe Institute and Harvard University.

Professor Myer was Chief Architect for the new Massachusetts Archives Building which was opened on November 19 of this year. The Archives contains a library, museum, records center and permanent home for the state's rich store of historical materials. Professor Myer's firm, Arrowstreet, Inc., was awarded the commission in 1978 by the state Designer Selection Board. The Arrowstreet design team also included Professor Rosemary Grimshaw and Susan Myers (March '77).

Other faculty outside honors and activities included The New England Concrete Masonry Association Award of Merit given to the firm of Imre and Anthony Halasz for their design of St. John of Damascus Church in Dedham, MA. Professor Beinart commenced work for the city of Jerusalem on the future development of the Israel Museum Hill Complex. Professor Ronald Lewcock was technical coordinator of the UNESCO international campaigns of Sana and Wadi Hadramant and Shiloam. Institute Professor Emeritus Jerome B. Wiesner received the Arthur M. Bueche Award from the National Academy of Engineering and an honorary degree of Doctor of Science from Tufts University.

JOHN R. MYER

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## Department of Urban Studies and Planning

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On April 18 and 19, about 200 alumni, faculty, and students gathered at MIT to commemorate 50 years of offering professional education in city planning at the Institute. It was an opportunity to reflect about the way the field has changed and the directions that individual careers have evolved. John T. Howard MCP '36, a member of the first graduating class who later returned to teach and head the department was especially recognized, along with the late Frederick Adams, the founder and department head for the first 20 years.

The anniversary gathering emphasized just how much the field of planning has developed over its half century at MIT. From a tiny program, located administratively in the department of architecture, with one professor, several part-time faculty and a handful of students, it has become a department with 50 faculty and academic staff, almost 200 students and an alumni roster of over 800. It is the oldest planning program in the United States, the largest, by far the most diverse, and we believe the best. It has the special responsibility of educating many of the educators of planning and is looked upon as the place where innovations in education and research are expected. There is confidence among faculty and alumni that these traditions can be continued.

### EDUCATIONAL PROGRAMS

The year marked two firsts on the educational front. In October, a special ceremony was held at Endicott House to commemorate the first graduates of the new master of science in real estate development program. The interdepartmental degree program was developed largely by faculty in the department, under the leadership of Professor Lawrence Bacow. The first graduates were highly successful in landing jobs in both the public and private sector, and the educational program has already spawned imitators at several other universities.

In the June graduation ceremonies, degrees were awarded to the first students to complete our new developing areas optional track in the master in city planning program. These students, drawn from the United States and around the world, will be accepting assignments in aiding less developed regions and countries in achieving the economic, social and environmental development necessary to improve standards of living. Professor Ralph Gakenheimer and Senior Lecturer Alan Strout have capably ushered the new program into existence.

At the same time as our new graduate programs develop and expand, the number of Course XI majors remains small. We continue, however, to enroll many students in our undergraduate offerings, taking heart that we are adding to the general education of architects, engineers and scientists. Professor Gary Marx, who coordinated our undergraduate program again this year, was active in Institute-wide committees reassessing the future of undergraduate education at MIT. We look to the future with the hope that undergraduates will make a more diverse set of career choices in the future.

At the graduate level, our master in city planning program remained viable, with applications about level and 35 new students enrolling. The high cost of education, however, has taken its toll in requiring many of our students to do outside work while they are studying. For some, this is a useful extension of their studies, but the competing claims on their time place a premium on personal organization. The demand for graduates of the program was higher than in recent memory, with a number of organizations sending representatives to interview and recruit. Professor Phillip Clay served as the director of the MCP program.

Thirteen Ph.D. students began their studies this year, working with faculty in a diverse set of fields. We are continuing in our efforts to stabilize our doctoral program at about 65 students in order to assure a greater level of faculty contact and support for students. While the number of graduates was disappointing, a large number of completions are planned for the coming academic year. Professor Lawrence Susskind directed our Ph.D. program in the fall, and Langley Keyes assumed the responsibility in the spring, upon his return from professional leave.

During the academic year, the faculty and the corporation approved our petition to begin offering master of science degrees in urban studies and planning, which we will award to students who spend a year of specialized research and study in the department. While only a small number of students are expected to do so in any year, the new degree offers greater flexibility to students than our professional MCP program.

Our two special programs also had successful years. The Special Program in Urban and Regional Studies for developing areas (SPURS), under the direction of Professor Lloyd Rodwin, enrolled a total of seventeen fellows and three SPURS associates. By country of origin, the fellows included: two each from Bolivia, Columbia and Thailand; one each from Haiti, Venezuela, Tanzania, Tunisia, Turkey, Israel, Italy, Philippines, India, Butan and the United States. Thirteen of the fellows are returning to their positions in the public

sector, and four will go on with their academic studies, two of whom will be in our MCP/developing areas program. The three SPURS associates were Dr. Ishwar Gupta, a professor of urban history at the University of Delhi, India, Dr. Mafuku Kintambu, professor of economics at the University of Kinshasa, Zaire, and Sundararajan Srinivasaraghva, senior planner at the planning commission, Government of India.

The Community Fellows Program, directed this year by Adjunct Professor Melvin King, enrolled eight fellows, six of whom came under a new arrangement of joint sponsorship by city governments and foundations in the fellows home community. Two fellows each came from Chicago, Newark and Charlotte, all communities with mayors of color in which there is an important need to develop further leadership in traditionally under-represented communities. A special focus of the fellows' investigations this year was the problems of youth growing up in inner city communities. Additionally, a grant from the Lotus Educational Foundation allowed a new program to begin in the use of computers in non-profit organizations specializing in community development. Community fellows, students and faculty worked with several community development corporations in Cambridge and Boston, helping staff develop the skills to use micro-computers in their day-to-day work.

#### FACULTY

A complete catalogue of faculty activities and accomplishments would take many pages, so only a few are noted here.

Professor Lawrence Bacow was on sabbatical and professional leave, practicing and doing research in the field of real estate development in which he so capably teaches.

On May 1-2, Professor Phillip Clay organized an international symposium on neighborhood policy at MIT, attended by many from the United States and abroad, comparing particularly the experiences in neighborhood upgrading in Israel and the United States. During the year, he continued his work on low income housing options and edited an important new volume, The Emerging Black Community of Boston.

During the spring, Professor Robert Fogelson spent his sabbatical in Spain, completing his manuscript on the social and architectural history of armories.

Professor Joseph Ferreira again served as the director of the computer resource laboratory of the school, extending the development of this critical facility.

Professor Aaron Fleisher continued his research on design methods, under a grant from NSF.

Professors Bernard Frieden and Lynne Sagalyn are nearing completion of their book on public-private arrangements in the redevelopment of downtown commercial centers. Professor Frieden was also honored by his colleagues at MIT by becoming chairman-elect of the MIT faculty.

Professor Ralph Gakenheimer had an active year in advising governments in Saudi Arabia, Bolivia and Indonesia on the development of urban transportation systems. A portion of his time was also spent as a visiting professor at the University of Lyon.

Professor Gary Hack was promoted to full professor, and in addition to serving as department head, he led an eight week urban design studio for American and Chinese students at Tsinghua University in Beijing. He returned to China in November to speak to the mayors of the country's large cities on urban development policies.

Professor Bennett Harrison had an active year of publications and research, continuing his work on industrial policy. He was guest editor for a special edition of Industrial Relations.

Professor Langley Keyes returned to the faculty after a three year leave as a special advisor to the Massachusetts Secretary for Communities and Development, where he led the efforts at providing housing for the homeless, developing new policies and programs for creating affordable housing, and synchronizing industrial and community development policies.

Professor Merrie Klapp spent the spring on leave as a visiting fellow at Oxford University, continuing her work on the politics of decisions in which scientific risks are crucial.

Professor Richard Larson was on sabbatical leave, doing research on the psychology of queing and new methods of police deployment.

Professor Tunney Lee completed three years as deputy commissioner of the Division of Capital Planning and Operations of the Commonwealth, and prepared to return to the department in August as department head.

Professor Gary Marx's work on surveillance systems received a great deal of national attention, as these issues found their way onto the public agenda. In addition to a large number of publications, he organized a faculty study group on technology, society and privacy.

Professor Karen Polenske's research and lecturing took her to France, the Soviet Union, China, Tunisia and Japan over the past year. She continued her research work on the economic impacts of infrastructure construction and rehabilitation.

Professor Martin Rein co-directed studies in Germany and Luxembourg on the welfare state and incomes, and wrote widely on the subject.

Professor Lloyd Rodwin directed a special study on Shelter, Settlement and Development for the UN Center for Human Settlements, an activity preparing for the International Year of Shelter for the Homeless.

Professor Bish Sanyal collaborated with Professor Judith Tandler on a study of the management of development activities in India, Bangladesh and Kenya. In addition, he helped coordinate the Special Interest Group in Urban Settlements (SIGUS), a joint effort with the department of architecture. Professor Tandler continued her work on private and voluntary organizations in economic development.

Professor Donald Schön spent the spring on sabbatical pursuing his studies on education for design. This year he again coordinated the faculty study group on design methods, involving faculty from four MIT departments.

Professor Mark Schuster ably served as assistant department head and had an active agenda of research on funding of arts activities. He completed an important study of corporate sponsorship of the arts, and consulted broadly to organizations around the world on arts funding policies.

Professor Lawrence Susskind was executive director of the program on negotiation for the third year and continued his work on mediation techniques in public disputes.

Professor William Wheaton did an important longitudinal study of the national office market and began work on the suburbanization of metropolitan employment.

A number of new part-time faculty made special contributions over the year. James Carras taught a subject on financing community economic development. Edward Logue brought his many years of experience in management of public and non-profit development agencies to our department in the form of a spring semester subject. Robert Sutcliffe, visiting from the University of Massachusetts, taught a subject on planning in socialist countries. Alfred Van Huyck brought field expertise in third-world development to the department, and helped organize a network for jobs and field placement of students. And Roger Simmonds, on leave from Oxford Polytechnic, taught urban design and implementation techniques.

Professor John Forester of Cornell University, spent his sabbatical with us, and did an assessment of our core teaching of planning theory.

Professor Yohel Camayd-Freixas resigned his position to become director of research and evaluation of the Boston School Department.

#### LOOKING AHEAD

In August, this author completes his term as department head, with the responsibility shifting to the capable hands of Professor Tunney Lee. A special word of thanks is due Professor Mark Schuster who aided in so many ways as assistant department head, and to Dean John deMonchaux whose support of the department and guidance were unfailing.

GARY HACK

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## Aga Khan Program for Islamic Architecture

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The Aga Khan Program for Islamic Architecture (AKP), established in 1979, functions jointly at MIT and Harvard University to promote research and teaching concerning architecture and urbanism in countries with Islamic societies. Generous gifts from His Highness the Aga Khan support the AKP through endowed funds that provide for faculty, student financial aid, library facilities and research; additional current funding supports publication, documentation, student travel and outreach activities.

The 1985-86 academic year was the first in the AKP's second cycle (1985-1995); it was marked by the consolidation of activities which had proved their worth in the first cycle (1979-85) and the launching of new activities aimed at extending and broadening the work of the Program. Mr. Y.R. Isar, on leave of absence from Unesco, came to the AKP's central office at MIT as director in January 1986; the role of this central office is to provide continuous liaison for activities carried out at both universities as well as to facilitate the coordination of joint, Program-wide activities.

### Faculty

An Executive Council has been formed to direct the AKP whose members are Professor Oleg Grabar, Aga Khan Professor of Islamic Art and Architecture at Harvard, Professor Ronald B. Lewcock, Aga Khan Professor of Architecture and Design for Islamic Cultures at MIT (Chairman), Professor William L. Porter, Professor of Architecture and Planning, and Professor Francois Vigier, Charles Dyer Norton Professor of Regional Planning, Harvard University. Other MIT faculty include Professor Yasser Tabbaa, Aga Khan Assistant Professor of Architectural History, who was on leave during the Spring 1986 semester and was replaced during that period by Professor James Dickie. An Instructor/Research Associate is soon to be appointed in the S.M. Arch. S. program, and funds have been negotiated to permit the appointment of a Lecturer/Associate Professor on a contract basis in that program in the next academic year.

### Academic Programs at MIT

Nine students were enrolled in the first year of a new two year course entitled "Design for Islamic Cultures" leading to the Master of Sciences in Architectural Studies degree. A further eight or nine students are due to be enrolled in 1986-7, bringing the total number of students at any one time to around sixteen to eighteen. The unit focuses its reflection and debate on both practical and theoretical issues characteristic of non-Western societies: appropriate responses to climate, building materials and building technology; sociocultural attitudes and values which have a direct bearing on the relationship of man to his environment. Beginning at the urban scale the regional characteristics of indigenous architecture in Islamic societies in Asia and Africa were analysed, then an example in which a contemporary architect had designed a large scale building in such a context. In the Fall semester the old city of San'a' was selected as the first example, followed by the Capital complex (Sher-e-Banglanagar) in Bangladesh; the semester ended with a short workshop considering differing attitudes to infill design in the context of existing environments. The Spring semester studio was intended to provide the students with an opportunity to design a major intrusion into an old fabric; for this purpose the nucleus of the new Gulf University in Bahrain was selected; during the semester a practical building workshop also exposed students to materials and methods of construction used in Africa and Asia which are unfamiliar in the West, to make possible greater appropriateness in the choice of technologies and the means of upgrading them for the purpose of low cost building.

Under the History, Theory and Criticism Program in the Department of Architecture, S.M. Arch.S. and Ph.D. students were offered courses on the history of Islamic architecture, the sociology of the Islamic city and Islamic theology and institutions. The students' areas of study included comparative approaches to architectural and urban form in different parts of the Muslim world; two thesis topics are multi-unit commercial housing in medieval Cairo and eighteenth century residential quarters along the Bosphorus in Istanbul.

### Student Support

Tuition and living expenses for two doctoral students and nine S.M. Arch.S. students were funded in whole or in part. Nine summer travel grants were awarded to 12 students from Harvard and MIT (including three joint projects involving two students together) for study trips to India, Malaysia, Morocco, Pakistan, South Africa, Spain and Turkey.

### Library and Information Resources

Specialized acquisitions and services at the Rotch Architecture Library continued to be provided through endowed funds. Under its Information Services and Technology Project, the AKP's visual documentation center has progressed steadily towards completion of a prototype Images System which integrates database management and graphics with videodisc technology. Some 30,000 images of Islamic buildings will be included in this innovative visual archive system. A custom designed user interface for the retrieval of images from the videodisc will allow scholars and designers to work within a personal computing environment. The completed prototype is expected to be ready for testing by the end of 1986.

### Seminars

Highlights of the year included AKP sponsorship, together with the Department of Fine Arts at Harvard and the Festival of India, of an international symposium on Fatehpur Sikri, the "City of Victory" constructed by the Moghul Emperor Akbar in the sixteenth century. The proceedings of the symposium will be published by the Indian journal Marg.

Another summer seminar was held at Kuala Lumpur, August 4-6, 1985 and was co-sponsored by the Malaysian Institute of Architects. An outgrowth of a design studio held concurrently by students at MIT and two Malaysian institutions, which dealt with the problems of improving an overdeveloped area in the city known as the Golden Triangle, the symposium itself broadened the subject to the problems of high-density development all over the world, and sought appropriate solutions for commercial development in the tropical city.

RONALD B. LEWCOCK



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## Center for Advanced Visual Studies

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The Center for Advanced Visual Studies (CAVS) has continued its integrated work exploring collaboration between artists, scientists, and engineers and developing new media for expressive, predominantly artistic purposes.

In keeping with the Center's interest in collaborative effort of architectural and environmental scale several CAVS group projects have involved artist Fellows and scientists and engineers from MIT at large: "Monocle" - a commissioned Center contribution to the "Mehr Licht" survey of contemporary art-and-science work with light as the principal medium at the Hamburger Kunsthalle, July-September, 1985, Hamburg, Germany, involving Center director Professor Otto Piene, fellows Lowry Burgess, Paul Earls and Christopher Janney, former fellow, Joe Moss, and others July-September 1985; it was shown again, in part, as a "Tribute to Gyorgy Kepes" the founding director, at the Center in November 1985.

Center group work continues on concept and execution of "Lights-Orot" (Sight/Insight) for the Yeshiva University Museum, New York. The extensive exhibition is scheduled for a long duration at Yeshiva University and at other museums in 1987, 1988 and further. It will use contemporary media of art and technology to interpret religious content in a museum context.

Professor Piene and a large group of CAVS fellows and former fellows contributed the major portion of the "Between Science and Fiction" section of the 1985 Sao Paulo Bienal, a large international survey exhibition of contemporary art in Sao Paulo, Brazil in the fall of 1985.

With current and former Center fellow artists Joan Brigham, George Greenameyer and Paul Earls and a crew of artists and volunteers Professor Piene designed and executed "ZODIAC" a large-scale installation and performance on Boston City Hall and City Hall plaza for First Night the 1985/86 Boston New Year's Eve public celebration. The project was funded primarily by an InterArts program grant from the National Endowment for the Arts (NEA).

Center artists and invited guest participants executed "Desert Sun/Desert Moon" an environmental installation and series of events in the Lone Pine, Ca. section of the Alabama Hills between Owens Valley and the High Sierra Mountains, June 8-16, 1986. Some major participants were Center artists Lowry Burgess, Paul Earls, Elizabeth Goldring, Christopher Janney, Professor Piene, and former fellows Dale Eldred, Ron Hays, Charlotte Moorman, Tal Streeter, Tom Van Sant. SMVisS program graduate students David Atherton, Shawn Brixey, and Laura Knott contributed "Photon Voice" a participatory piece using solar energy translated into several light, sound, and movement media. In addition to a major grant from the NEA InterArts program extensive materials contributions supported the eight-day series of desert activities which were fully documented by a Smithsonian World program film crew and by CAVS video artist Vin Grabill.

"Desert Sun/Desert Moon" was the overture to the SKY ART Conference 1986 at MIT. It is intended to be the concluding conference in a series of four. After the 1981 at MIT, the 1982 as part of the ARS ELECTRONICA in Linz, Austria, and the 1983 Conference in Munich, the fourth is scheduled for September 29 - October 4 in various locations at MIT and in Boston, with telecommunication events connecting other locations internationally.

Individual work by CAVS Fellows: Joe Davis has developed several versions of "light mikes" for light-sound transmission over a wide range of distances.

Paul Earls composed "Augenmusik" for contemporary music ensemble and laser performed by Richard Pittman and the Boston Musica Viva at Harvard Loeb Theater, March, 1986.

Elizabeth Goldring and Vin Grabill contributed a collaborative video tape on decaying human vision, "The Inner Eye: From the Inside Out" to "Vision: The Precious Treasure" an exhibition travelling to twenty U.S. science museums.

Christopher Janney composed, designed, and produced a series of performances, "Soundworks", at the Washington, D.C. Kennedy Center for the Performing Arts, March, 1986.

Former director and CAVS founder, Institute Professor Emeritus, Gyorgy Kepes' work is presented in a series of retrospective exhibitions in museums of his native Hungary.

CAVS director, Professor Piene, participated in "German Art in the 20th Century" at the Royal Academy of Arts in London and the Staatsgalerie, Stuttgart as well as in "Kunst in der Bundesrepublik Deutschland 1945-1985" at the Nationalgalerie in Berlin. He developed and flew "Sun Valley Neon Rainbow" for the Sun Valley, Idaho, Center for the Arts July, 1985 and contributed to "ZERO: Mack, Piene, Uecker" at Kunst-

verein Lingen, Germany, October, 1985.

In the CAVS-provided environmental art section of the SMVisS graduate program the following theses were submitted: Ebon Fisher: PASSION IN SCIENCE AND ROCK MUSIC: A Comparison of Two Faiths; Ellen Sebring: MUSICAL FORM IN NON-NARRATIVE VIDEO.

Former CAVS Fellow, Todd Siler, completed his PhD thesis on ARCHITECTONICS OF THOUGHT: A Symbolic Model of Neuropsychological Processes.

CAVS undergraduate offerings served approximately 250 students Institute-wide in such subjects as "Art and the Environment"; "The Artists Speak: Aspects of Performance"; "Life Drawing" and "Basic Photography for Architects".

OTTO PIENE

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## Center for Real Estate Development

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The Center for Real Estate Development (CRED) has completed its second full year of operation. On October 16, 1985, Provost John Deutch provided the highlight of the year by awarding 35 degrees to the first graduates of MIT to receive the degree of Master of Science in Real Estate Development. Two additional joint degree candidates in this class received their degree at the June 1986 commencement.

With start-up activities now behind us, attention has turned to longer term issues, none being more important than securing a stable, long-term financial base for the Center. To this end the Center has announced a \$10 million fund-raising effort and is seeking funding for named endowed and term faculty chairs; named endowed and term research grants; and named fellowship support for graduate students in the program. In addition, each year the Paul Samuelson Fellows will have the opportunity to spend a four-month period of residence at MIT, to coincide with a fall, spring, or summer semester. Samuelson Fellows will be drawn from distinguished industry and academic leaders in the field of real estate development.

The Center has already received over \$3 million from industry to launch its start-up and first two years of operation. It is now supported by some 100 member organizations representing development companies, financial institutions, architects, lawyers, engineers, public agencies, and non-profit groups. This list has grown from the original 64 U.S. founding members in 1984 to include international representatives from Canada, Japan, England and Holland. Two members meetings were held in the past year. A regional meeting was held in December 1985 in Washington, D.C. on the topic of negotiated development rights. The June 1986 Boston meeting provided the members an opportunity to meet with senior faculty and researchers in economics and management. The topic of this recent meeting was The Impact of National Economic Trends on Real Estate Development.

Through the generosity of Ernest Hahn, a member of the Center, a three-part lecture series was offered to the public in the Spring of 1986. Raymond Nasher, founder and chairman of the Nasher Company of Dallas, gave the first lecture on "Humanizing the Environment Through Development." Bernard Ghert, president and CEO of Toronto's Cadillac Fairview Corporation, gave the second lecture on "Managing the Large Development Company", and Kent Colton, Executive Director of the National Association of Home Builders, delivered the final lecture on "Housing America: The Challenges and Opportunities That Lie Ahead."

During the summer of 1986 a series of two- and three-day professional development courses will be presented on such topics as Technology and the Housing Industry, Marketing Real Estate Developments, Winners and Losers in Changing Real Estate Markets, Negotiating Skills for Real Estate Professionals, Value Creation in Real Estate, Financing Real Estate Through Equity Capital, Developing the Extended Care Community, Population Trends and Their Impact on Portfolio Management, and Capital Markets for Real Estate Development.

The education program continues to share a close association with, and faculty support from, the departments of architecture; urban studies and planning; civil engineering and the Sloan School. Rapidly expanding class size, participation in classes by a broad spectrum of MIT and Harvard students, and a sustained high ratio of applicants to admitted students are evidence that many of the original objectives for the graduate program and its eight core courses are being met.

Current research projects include: "Dynamics of Microeconomic Factors Shaping the Future of the Real Estate Industry" (Paul Samuelson); "America's Office Needs: 1986-1996" (David Birch); "Evaluation of Low Income Housing Strategies" (Phillip Clay); "Public/Private Partnerships in Development (Bernard Frieden/Michael Joroff); "Adaptive Reuse of Historic Buildings Within National Parks" (James McKellar); and "The Affordable Housing Task Force" (Langley Keyes). This last project is part of a major research thrust of the Center; affordable housing is a crucial issue confronting the development industry now and in the foreseeable future.

In response to continued growth the Center has made some organizational changes. Charles H. Spaulding is now Chairman of the Center. James McKellar has become the new Director, moving from the position of Director of Education that he had assumed from Lawrence Bacow, who is currently on leave. Michael Wheeler, former Director of Education and Research at the Lincoln Institute of Land Use Policy in Cambridge, takes over as Director of Education in August 1986.

With the appointment of a new Advisory Committee comprised of faculty, alumni, and members, the Center will be undertaking new initiatives to review the curriculum, assess research priorities, and guide fundraising efforts. This next year is seen as a transition from the concerns of getting started toward a maturing of the Center's education programs and research activities.

JAMES MCKELLAR

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## Laboratory of Architecture and Planning

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### GENERAL BUSINESS

This year the Laboratory of Architecture and Planning has gone through several changes while continuing to serve as the administrative base for all planning and architecture research of the School of Architecture and Planning. Other research of the School is based in the Media Laboratory. The LAP this year, as planned, transferred administrative responsibility for the Center for Real Estate Development and the Aga Khan Program to each of the respective units; however, CRED and AKP sponsored research efforts are still administered through the LAP, and 1985-86 has brought a strong emphasis on real estate development and related topics to LAP research.

### PROGRAMS

In keeping with the growing interest in the technology of buildings within the School, as articulated by the School Council in its research agenda, research initiated this year has explored both building technology and building systems.

Of major import this year, the Laboratory, with the Dean of the School and representatives of the CRED, was instrumental in shaping the agenda of the Harvard-MIT Joint Program for Housing Studies. The proposed research agenda promotes an investigation into the areas of building technology and housing futures; research currently underway explores housing market phenomena, new technologies for housing, and cross-cultural comparative research strategies in the housing and construction fields; special emphasis is being placed on manufactured/prefabricated housing, reviving a line of research with a powerful tradition at MIT. James McKellar of the CRED, and Mary Dolden of the LAP, are involved in the implementation of the JCHS agenda and the ensuing research programming. GTE Industries awarded the School \$100,000, to be disbursed over a period of five years (and administered by the Laboratory) toward the construction and implementation of a lighting laboratory. Plans for the facility are being reviewed, and construction should commence upon selection of an appropriate site. This is a welcome outgrowth of the work in modelling done by Professor Bryan of the Architecture Department and Professor Glicksman in Mechanical Engineering, and by George Clark, Research Affiliate and lecturer in lighting.

The Grunsfeld Research Incentive Awards continue to provide a very important source of funding for small scale exploratory research by students and faculty. This year's awards went to: Jack Myer for a project which will document and archive present activities in the School; Reinhard Goethert and Nabeel Hamdi as funding for initial exploratory work to develop joint research efforts, with the University Catolica de Chile, into rapid needs assessment techniques for low income areas (with specific reference to the Chilean context); Sandra Howell to supervise the compilation and analysis of cross-cultural data on habitability patterns in developing and post-industrial societies, with a particular emphasis on the Japan-US comparison; Imre Halasz to support a seminar/workshop which, using Boston's Fort Point area as a model, will develop an urban infrastructure scheme synthesizing centralized and decentralized design decisions as a means of exploring the methodology for establishing design guidelines; Ronald Lewcock and Akhtar Badshah for a study of the unique morphology of the Islamic city; John Habraken and Stephen Kendall for the continuation of research into building alternative 2x4 construction system vocabularies; Jan Wampler for completion of the ILAUD "Edges" project (including a partial model of the Santa Maria Della Scala in Siena), to be presented at MIT as an exhibit in the fall of 1986; Patrick Purcell to enhance research already conducted on the uses of microcomputers in design by exploring the possible uses of the new laser disk technology -- and issues attendant to that use -- through the creation of a pilot disk system; Ranko Bon for a study of the Japanese housing and construction sector, using the input-output tools of macroeconomic analysis; and Eric Dluhosch for the development of an integrated classification "language" for describing the processes, materials, components and functions used in construction.

The East Asian Architecture and Planning Program (EAP) continues to grow, and this year's activity sees the Program becoming a real presence in East Asia, with strong university and industry contacts established in Japan, China and the Republic of Korea and developing relationships in Hong Kong, Singapore and Taiwan. Under the auspices of the EAP, the Laboratory sponsored workshops in Japan and Korea on building technology and real estate development; planned events include special seminars on planning and new communications technology, public-private partnerships in real estate development, and comparative R & D tactics in the construction and housing industries. The second annual EAP conference took place in Osaka in April of 1985 and planning continues for the third conference to take place in Seoul (subject: Large-scale one-time developments and their impact on city planning). During the summer of 1985, the EAP, in collaboration with Qinghua University, sponsored an innovative

urban design studio in Beijing, China for students from Qinghua and American universities. This studio will be offered biannually. As a continuation of this summer studio program, the EAP is sponsoring a studio on historical preservation in Kyoto and Nara, Japan, during the summer of 1986. During this past academic year, the EAP sponsored a seminar (at MIT) in the Department of Urban Studies and Planning on comparative urban development, "Neighborhood Transformation: Beijing, Seoul, Tokyo". Now that the EAP has established itself as a strong networking facility for academics and practitioners, we hope to create academic programming at MIT and in collaboration with other institutions to explore those topical areas that initially prompted the creation of the Program. Several cooperative programs have emerged from contacts established through the East Asian Program. The Korean Institute of Construction Technology-MIT Cooperative Research agreement will be continuing into its third year in 1987. The terms of a cooperative research agreement with the Shimizu Construction Co., Ltd., Japan's second largest construction firm, were finalized in the fall of 1985 and the contract was signed in February of this year. Research conducted under this umbrella contract will include comparative industrial studies and exploration of building technology topics. Negotiations to establish a research program with the Mori Building Company, Japan's third largest owner of real estate, were completed this year. Research proposed to the Mori company includes investigation into comparative study of public-private partnership in real estate development in Japan and the United States and will be carried out collaboratively with the University of Tokyo.

#### NEW RESEARCH

Jim McKellar (CRED) is the Principal Investigator for a project which falls under the recently finalized cooperative agreement between the CRED and the National Parks Service--North Atlantic Region. Work done under the agreement aims to assess the potential for the involvement of the private sector in preserving designated historic sites; the current project refers specifically to Riis Park, located in the Gateway National Recreation Area, New York.

Lois Craig and Mary Jane Daly serve as co-Principal Investigators for the Governor's Design Awards Program, a new awards program sponsored by the Massachusetts Council for the Arts and Humanities. This innovative program seeks "to recognize and encourage improved design" in the Commonwealth of Massachusetts, and brings together a variety of artists and designers from around the state. The Governor's Design Awards Program continues a tradition in the School of Architecture and Planning of examining and developing citizen participation models of lasting value to public and private development efforts. The first awards will be made by Governor Dukakis in December of this year. Michael Joroff and Eleanor Westney have begun researching the R & D process in the Japanese construction industry. This major effort is funded by the National Science Foundation, and forms the core of a large body of comparative research into the Japanese construction industry being conducted by faculty and researchers in the School. In addition to the National Science Foundation, support for these research efforts is provided by the Mori Foundation, the Shimizu Construction Co., the MIT Center for Real Estate Development, and other private sponsors.

Ranko Bon continued his exploration of building economics this year with a project for the US Army CERL on "Real Property Strategies Assessment". This project involved the evaluation of property utilized by the US Army, taking into consideration multiple factors, such as security, life-cycle costing, etc..

Eric Dluhosch completed the first phase of work on the computer-based educational package designed for the International Masonry Institute. The resulting product, "Masonry Compute", combines an existing data base with a videodisk component and drawing module to provide a tool for designing with masonry; the product has met with success and further work on the package will continue next year. Donald Schon and Lawrence Bucciarelli received a grant from the National Science Foundation to support their project, "Generic Design Processes in Architecture and Engineering". This project will explore the processes and tools of design to build an understanding of its generic and domain specific features. Descriptions of these features will inform the development of better tools for designing, especially those which are computer-based.

John Habraken also received a grant from the National Science Foundation. "Design Games as Means for Experimentation in Design Theory and Methodology" is a project whose initial premise is that design is game-like activity; with this established, the project seeks to use games to test design theories and develop new operations.

In addition, the School of Architecture and Planning, through the Laboratory, submitted a major proposal to the U.S. Agency for International Development that provides a broad range of research and training services. Professor Ralph Gakenheimer and Dr. Reinhard Goethert would serve as coordinators of the program.

## CONTINUING RESEARCH

In addition to the above, the Laboratory of Architecture and Planning serves as home base to several ongoing projects and inquiries. David Birch's research into changes in neighborhood and regional business demographics continues, and this year his focus has been on the long-term demand for commercial office space in the United States, research funded by Arthur Anderson, Inc. and the MIT CRED. Karen Polenske has also been devoting effort to the study of regional growth in the United States and China and she has expanded her work on studying the economics of infrastructure redevelopment with funding from the U.S. Department of Commerce and private foundations. Reihart Goethert and Nabeel Hamdi continue their work for the Ministry of Housing in Sri Lanka, concentrating on housing and construction in a Third World setting. Michael Joroff and Ranko Bon developed a second phase of research about comprehensive building performance for the Real Estate and Construction Division of IBM. The development of a collection of architectural case studies continues, under the direction of Michael Joroff; a catalog of available cases is being prepared in collaboration with the Bartlett School of Architecture in London and will be forthcoming in the Fall of 1986. John Klensin continues his work with the Infoods project, an ongoing effort to develop facilities for international exchange of data on nutrient composition of food. The project is funded by the National Institute of Health.

The LAP continued to serve as the home base for the Environmental Impact Assessment Review, now published in its fourth year, by Elsevier Press. Professor Lawrence Susskind is the Senior Editor and LAP Research Associate Terry Hill is Editor. Open House International, a journal of housing, continues to be published by the LAP and several other schools in the U.S. and England. Nabeel Hamdi serves as co-editor.

## PERSONNEL

Kathleen Reid, the LAP's Administrative Officer, left MIT for private industry. Mary Jane Daly rejoined the LAP as a Research Associate after an extended leave of absence and Cindy Woolley joined the LAP as a member of the support staff.

MICHAEL L. JOROFF

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## Media Laboratory

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The Media Laboratory has completed its first full year in the Wiesner Building, a \$45 million facility dedicated on October 2nd, 1985. During this period, the Laboratory witnessed approximately 100 percent growth over the previous year in research funding, topping a \$4 million annual budget, exclusive of grant funds and academic budget.

Seventy-five corporate sponsors constitute the founding group of investors in the idea that it is imperative to couple the invention and creative use of new communications media. Five new industrial sponsors joined the Lab this year. They are: Hughes Aircraft Company, Bell-Northern Research, Bandai Company, Pioneer Electronic Corporation, and Nippon Gakki Co., Ltd. (Yamaha).

As part of the Laboratory's start-up, eight major hardware grants added to the computer facilities already unmatched anywhere on campus. Hewlett Packard provided a \$5 million gift to promote the use of workstations in artificial intelligence research. This grant has resulted in a growing population of the H/P "Bobcats" (HP9000 series 300). These powerful workstations have provided a true computational link between every group in the building. Yamaha has contributed processing, mixing, and production equipment for electronic music research, and to a lesser extent, film/video, and speech research. The Sony Corporation has granted \$250,000 of digital audio equipment for use throughout the building. A major equipment grant was also provided by Apple Computer, Inc. This equipment will primarily be used by the Entertainment Research Group and the Visible Language Workshop. Compugraphic Corporation has given a high quality photo-typesetter which, as a node on the building network, will provide the Lab with camera ready copy. Finally, both Digital Equipment Corporation and Wang Laboratories, Inc., each of whom granted hardware in excess of \$3 million last year, have reconfigured or extended their gifts to meet the changing needs of the Laboratory.

In parallel with the above, the Laboratory has acquired the first Connection Machine delivered by Thinking Machines, Inc. of Cambridge, Massachusetts. This massively parallel computer (16,000 processors) moves the Laboratory's computing resources into a new period of modern thinking and hardware experimentation.

The Laboratory continues to be one of the most often visited MIT facilities by the Industrial Liaison Program. Over 600 groups were hosted this year, within and outside the aegis of ILP. This steady stream of corporate and international interest is an indication of the Laboratory's continued uniqueness in the world. Further indication of such interest is reflected in the fact that the Media Laboratory was chosen to host Technology Day this year.

The year closes with the beginning of the final construction of the Villers Experimental Media Facility, a unique, large scale experimental space at the core of the building. At its periphery will be added computer facilities, built for computer graphics and animation and expected to house a major hardware grant from Gould Inc.

### CURRENT RESEARCH ACTIVITIES

The Electronic Publishing Group, under the direction of Associate Professor Andrew Lippman and Principal Research Scientist Walter Bender, is successor to the Architecture Machine Group. Its primary research program this year involved the collection, organization, and dissemination of what is traditionally thought of as "news". This group developed an interactive, personalized, hard and soft copy news information system: NewsPeek. This "newspaper of the future" was made up of formerly separate news sources such as newspapers, magazines, electronic mail, network television, photograph, and wire services which were edited by the computer into a single well organized and personalized interface. The group continues to enjoy large scale funding from IBM's Entry Systems Division.

A new DARPA contract was begun addressing command and control visual interfaces. Joining Associate Professor Lippman will be Associate Professor Stephen Benton (Spatial Imaging Group) and Principal Research Scientist Richard Bolt (Human Interface Group). The goals of this contract are the development of three-dimensional displays and interaction technologies, including a globe-like, touch-sensitive map.

Electronic Publishing is being expanded to include a new perspective on the motion picture industry. The "Movies of the Future" program was announced by President Paul Gray at this year's Technology Day. This program will be funded by the Coca-Cola Entertainment Business Group (Columbia Pictures), 20th Century Fox Film Corporation, Paramount Pictures Corp., and Warner Brothers Inc. It will address issues of imaging technology for home delivery of movies, copyright protection, production technology, and a new brand of data compression.

The Music & Cognition Group (formerly the Experimental Music Studio), under the joint direction of Professors Marvin Minsky, Barry Vercoe, and Assistant Professor Tod Machover, has reshaped its program's orientation to allow for a much broader application of computers to the musical experience. This year's primary accomplishment, under the direction of Professor Vercoe, has been the continued development and refinement of the Synthetic Performer, a machine recognition of performance and gesture enabling the computer to function as a skilled collaborator. In delineating and rendering various agreements understood by musicians into algorithmic designs, Professor Vercoe and his students have begun to explore the role computers will play in the creative process.

Professor Minsky and Assistant Professor Machover will be investigating the rules that govern creative play, hoping to move the computer from the role of accompanist to that of creative partner.

Assistant Professor Machover has recently completed "VILAS", a computer opera celebrating the 10th anniversary of Paris' Centre Georges Pompidou.

Remaining active in performance as well as research, the group's concert series performances this year included American Digital: Computer Music in America (Boston's first performance of recent American computer music), Music from IRCAM (presented in collaboration with Pierre Boulez's French National Institute de Recherche et Coordination Acoustique/Musique), and Interplay: Toward a Theater of Sound (part of the New Music Resources concert series).

The Film/Video Group, under the direction of Professor Richard Leacock and Lecturer Glorianna Davenport, presented its experimental video workstation at the National Association of Broadcasters' annual show in Dallas. Dr. Richard Zvonar was in residence for two months this year conducting research on the technical aspects of Professor Leacock's "Peace" project. His residency was made possible through a grant from the National Endowment for the Arts and the Council for the Arts at MIT.

"Remembering Niels Bohr, 1885-1962" a film by Ms. Davenport and Professor Leacock, was premiered at the American Academy of Arts and Sciences symposium on Niels Bohr in November.

The Entertainment Research Group, under the direction of Dr. Alan Kay, Professor Marvin Minsky, and with the assistance of Dr. David Levitt, has launched a new project funded by Apple Computer, Inc. The project suggests a new view toward machine intelligence, using the design and simulation of real and fantasy animal life as an epistemological handle on behavior and as a device for children to learn with. The work is being conducted in parallel with The Open School, a Los Angeles based public school, in which working prototypes are tested.

The Advanced Television Research Program is jointly housed both in the Media Laboratory and the Research Laboratory for Electronics. Under the leadership of Professor William Schreiber, the program is funded by a consortium of American television broadcasters and equipment suppliers. These included ABC, NBC, CBS, PBS, Harris, Tektronix, HBO, RCA, and 3M. Its goal is the development of the scientific and technological basis for the improvement of television systems. It is currently developing a computer-based simulation system for the entire television process from object to image. Motion compensation methods were developed for image enhancement, coding, and frame-rate conversion. In addition, considerable effort is being devoted to discovering the means of improving the efficiency of television channels, with the objective of obtaining maximum image quality for a given channel capacity.

Included in this program is the Laboratory's Audience Research Facility, under the direction of Associate Professor W. Russell Neuman. Its new facility was completed in a suburban shopping center and initial audience studies were started.

The ATRP Program was renewed for a second 3-year term, with a slightly modified membership.

The Epistemology and Learning Group, under the leadership of Professor Seymour Papert, celebrated its first year of observation in the "School of the Future" project. Through a competitive selection process a Boston Public School System primary school, The James Hennigan School, was chosen to conduct some of the most comprehensive experiments ever attempted in the field of computers and learning. Prior to the start of the 1985 - 1986 academic year, The Hennigan School was equipped with enough computers and peripherals to create a 1:1 ratio of machines to students. The teachers and some of the older students attended a special training program during July of 1985 to learn Logo, the computer language used in the project and to explore new teaching methods. The project is funded primarily by IBM.

Preliminary results confirm that Professor Papert's group is engaged in an educational experiment that may have major consequences in altering the way we think children learn.

Another development in the area of learning environments for children is the design of computer-controlled building blocks. This work has attracted the attention of psychologists, educators, and leaders in the toy industry. The industrial interest is reflected in a three-year, \$680,000 research contract with Lego Lego Systems, Inc., the manufacturers of the well-known Lego building materials.



This year the Laboratory again hosted LOGO' 85, an international conference attended by over 400 computer and learning enthusiasts from all over the world.

The Spatial Imaging Group, under the direction of Associate Professor Stephen Benton, has launched a major program in synthetic holography sponsored primarily by General Motors Corporation's Design Staff. The completion of the first year of this program was marked by the group's demonstration of the world's first free-floating, non-enclosed, 3-D hologram.

Exhibitions of the group's work were seen at the Silicon Valley Festival of Electronic Arts (Mike Teitel), The 2nd International Symposium on Display Holography at The Art Institute of Chicago (Julie Walker), the Morgan Gallery in Boston, the Wood Art Gallery in Vermont, and at the Messenpalast in Vienna, Austria (Mike Teitel and Julie Walker).

Art holograms by Betsy Connors were exhibited at the Thomas Segal Gallery (the first hologram in a major Boston gallery) and at the Brockton Art Museum. A hologram designed by Ms. Connors and Professor Benton was included in the exhibition at the Walker Art Center in Minnesota.

Associate Professor Toshio Honda of the Institute for Imaging Science and Technology, Tokyo Institute of Technology, visited the Spatial Imaging Group for three months to work on holographic recording in photopolymers.

The Computer Graphics and Animation Research Group is directed by Associate Professor David Zeltzer. This group is continuing the study and implementation of computer animation and display systems, including robotics, behavior modeling, and knowledge representation for the animation of articulated figures.

Work has been funded by Nippon Hoso Kyokai (NHK), Japan's public broadcasting corporation. A new project has been funded by The Bandai Corporation, Japan's largest toymaker.

The Visible Language Workshop (VLW), under the leadership of Associate Professor Muriel Cooper and Principal Research Associate Ronald MacNeil, is working on a broad range of issues involving computer graphics and communications. Topics regularly under study include expert systems in the design process, the camera as a computer peripheral, computer enhanced photographic processing, and object-oriented programming.

Research includes a five-year general computer graphics design workstation development project sponsored by Hell GmbH of Kiel, West Germany. IBM has sponsored work in font design and layout, tool construction, and interface research.

The VLW hosted two Design Forums bringing together professionals and MIT students from various graphic design disciplines to discuss and evaluate the designer's creative process.

The Human Interface Group, headed by Principal Research Scientist Richard Bolt, is directly confronting the computer interface. In conjunction with other Laboratory groups, Dr. Bolt is attempting to bring eyes, gestures, and speech into the computer interface. The group has successfully demonstrated how arm movement can be used as input for the computer. Last semester, the group began work on an eye tracking system which will allow the computer to understand what its user is looking at. Experiments have also begun in the area of speech recognition which employs a lip reading mechanism that guarantees a higher error free transmission rate.

The Speech Research Group, headed by Principal Research Scientist Christopher Schmandt, continues to research the role speech may play in the computer interface. Of particular interest to the group is speech as an interactive medium, versus one of transcription. Last year's primary project, The Conversational Desktop, was a voice driven network node which through the deft use of telephone and computer networks, could perform many duties now performed by a good secretary. Most important among these was its capacity (albeit limited) to understand and generate natural language. The parsing program will be further refined to include special attention to intonations and their meaning.

Also developed in the Speech Research Group was a phonetic spelling program. This software allowed children to phonetically input words they understood but seldom used because they were unable to spell. The program would then identify and display the correct spelling.

#### PERSONNEL

Changes and appointments continue to accompany the Laboratory's growth. Of major note this year is the appointment of Mr. Timothy Browne to serve as liaison for sponsors, potential sponsors, the press, and visitors. Having worked at the Metropolitan Opera House, NHK (Tokyo), Yomiuri Television (Osaka), and Time/Life Books, Mr. Browne is uniquely qualified to meet the Media Laboratory's liaison needs.

Other new appointments in the Laboratory include: Dr. Sylvia Weir's move to the Media Laboratory as Principal Research Scientist from the Laboratory of Computer Science, Henry Holtzman as Senior Systems Analyst and Jason Kinchen as Personal Computer Co-ordinator.

Other staff changes include Mrs. Ellen Liao (formerly: Ellen Robinson) and Ms. Lauren Zachmann's promotion to Administrative Staff.

NICHOLAS P. NEGROPONTE

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## School of Engineering

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The Long Range Plan of the MIT School of Engineering was reviewed and revised this year in the context of the Long Range Plan for MIT, issued in June 1985. The School places high priority on enhancement of its position of leadership in engineering education, and has undertaken a major initiative in collaboration with the Schools of Science and of Humanities, Arts and Social Sciences, to enhance engineering education in these areas, while maintaining the technical excellence which has characterized MIT's engineering education. To enable an improvement in the quality of life for both faculty and students, it projects a small reduction in the School's faculty size together with a reduction in graduate student numbers, to better match the available resources. Other School-wide efforts called for in the Plan include the diffusion of computer applications throughout the School to reduce the enrollment pressure on the Department of Electrical Engineering and Computer Science, and a major initiative in manufacturing.

A Commission on Engineering Undergraduate Education, chartered by the Dean of Engineering to lead the study of undergraduate education for the School, has worked within the framework of the Committee on the Undergraduate Program, to define the Objectives for Engineering Education at MIT, and to evolve means for their realization. The Objectives enunciated by the Commission include prominently as a key goal of engineering education an understanding of the diverse nature and history of human societies, their literary, philosophical traditions, as well as understanding of and respect for the economic, political, social, managerial and environmental issues surrounding technical developments. Placing these goals at the same level of priority as the more traditional technical goals of engineering education will, it is hoped, create an environment conducive to improvements being sought in the programs of the School of Humanities, Arts and Social Sciences. Other means for realization of the School's Objectives are under active study by the Commission in cooperation with the committees of the other schools and with the Committee on the Undergraduate Program.

The Manufacturing initiative, which is being undertaken in cooperation with the Sloan School of Management, is to lead to a major program of research and education to address those factors which limit US competitiveness in the design, development and manufacture of products for the world market. The School's objective is to focus the attention of its faculty, staff, and students on those technical and organizational issues where it is likely to be able to make a substantial contribution. An approach highly collaborative with industry is envisioned, wherein students and faculty would visit plants to gain first-hand knowledge of the approaches and problems of manufacturing, and industrial personnel would spend substantial periods at MIT, in collaborative research.

Large undergraduate enrollments continue to be a problem for some departments of the School of Engineering. Although the total enrollment of the School declined slightly, from 2361 in 1984/85 to 2301 in 1985/86, the enrollment in Aeronautics and Astronautics rose from 282 to 308, while Electrical Engineering and Computer Science (EECS) and Mechanical Engineering remain very high at 1121 and 443 respectively. The slight decline in EECS, from a (temporary) high of 1153 the previous year was encouraging, but advanced information on course selections at the end of the Spring semester indicates that the enrollment in EECS will rise again next year.

The graduate student population of the School increased from 2354 in 1984/85 to 2373 this year, with substantial increases in Aeronautics and Astronautics (13), Chemical Engineering (13), Civil Engineering (23), Electrical Engineering and Computer Science (20), and Materials Science and Engineering (25). A study is underway to determine whether or not these increases are due to increases in the time spent at MIT in candidacy for degrees, the MS in particular. Meanwhile, admissions are being lowered to reduce the numbers of graduate students in the heavily loaded departments.

With the trend in government toward funding of large interdisciplinary research programs in addition to (and to some extent in place of) the more traditional single-investigator projects, faculty of the School have devoted considerable effort this year to the organization of research teams and the writing of proposals for laboratories and centers. Last year the Biotechnology Process Engineering Center was funded by NSF as the result of such a proposal. This year a considerable number of proposals were written in response to the Department of Defense's University Research Initiative. As of this writing, we are aware of several successes. The Department of Civil Engineering will be funded for five years by the Army to study modern approaches to construction. The Artificial Intelligence Laboratory will receive support for work in robotics. The Center for Space Research also received support for work in theory/analysis of the geo-plasma environment, as did the Laboratory for Information and Decision Systems for intelligent control systems and the Department of Mechanical Engineering for structural and electronic polymers. In addition, MIT groups are listed as subcontractors on four awards to other universities. This total of nine successes represents an important measure of the quality of the MIT faculty, who have regularly attracted more than a prorata share of such support. The competition becomes increasingly difficult with time however, and the drain on faculty time for proposal preparation correspondingly more serious.

Another measure of success for the School is the number of its young faculty designated Presidential Young Investigators. This year six were so honored, including Professors Triantaphyllos R. Akylas for Fluid Mechanics/Stability; John F. Brady, Multiphase Fluid Particle Behavior; T. Alan Hatton, Extraction; Edward F. Crawley, Aerospace Engineering; Charles E. Leiserson, Special Purpose Architectures; and Tomas Lozano-Perez, Robotics.

The School continued its policy of offering positions to outstanding women and minority candidates. A key element of this policy is to seek minority and women faculty irrespective of the specific fields authorized for faculty searches. For the second year the policy also included funding of postdoctoral positions for women or minority candidates with good potential to become faculty members. During 1985-86 faculty positions were offered to four women. Three of the four women are currently employed in private industry and declined our offers in favor of remaining there. One of the four was unable to accept our offer for personal reasons.

Under the direction of Professor Leon Trilling, the Second Summer Program will enter its eighth year of operation in the summer of 1986 with 32 students and eight companies participating. The Program which started in 1979 with ten students provides an intensive summer educational and work experience to outstanding MIT minority engineering students following their freshman year.

The Institute has reaffirmed its commitment to the Minority Introduction to Engineering and Science (MITES) program, which each summer for several years has brought up to 40 minority high school students to MIT to sample its environment, meet representative faculty, and visit industrial installations in the Boston area. This year responsibility for MITES was transferred to the office of the Associate Dean of Engineering.

#### ENGINEERING INTERNSHIP PROGRAM

For the summer of 1986, 55 sophomores were placed in the Engineering Internship Program (EIP). The total enrollment is now 130 students with 29 companies actively participating in the Program. Beginning at the end of the sophomore year, the EIP provides work experience at a participating company during two undergraduate summers and one graduate summer and academic term. The Program leads to the simultaneous awards of the SB and SM degrees with the SM thesis done at the company during the graduate work experience.

A new company for 1986 was MBB-ERNO, Bremen, Germany, the Space Technology Division of MBB. This is the first foreign company to participate in EIP. Two sophomores were hired by MBB-ERNO to work on orbital systems and communications satellites, and on the system concept and project definition work for COLUMBUS, the European contribution to the International Space Station planned by NASA.

It is expected that several other foreign companies will be participating in the EIP within the next few years as the Program progresses toward its expected steady state level of about 180 students and 40-45 companies.

#### PROGRAM IN POLYMER SCIENCE AND TECHNOLOGY

The Program in Polymer Science and Technology (PPST), and interdepartmental program involving faculty from both the School of Engineering and the School of Science will admit its first class of seven doctoral students in the Fall of 1986. Over the past year, the faculty engaged in extensive development of its core curriculum. Advanced level elective subjects are also being developed. Jointly with the Department of Materials Science and Engineering, the PPST participated in a successful proposal to the IBM Materials and Processing Sciences Initiative for funds to support faculty, students, and equipment purchases.

#### MANAGEMENT OF TECHNOLOGY PROGRAM

This Program, directed by Professor Edward Roberts in the Sloan School of Management, leads to the SM in Management of Technology awarded jointly by the School of Engineering and the Sloan School of Management and is described in the Sloan School of Management section of this report. The Program is aimed at engineers and scientists with at least five years of work experience and is designed to prepare these professionals for more senior roles in industry and government where they will establish and manage technology-based endeavors. The enrollment in this 12 month intensive Program has grown from six in 1981-82, its inaugural year, to 29 this year.

#### SCHOOL APPOINTMENTS AND RESIGNATIONS

With Professor Myron L. Tribus' retirement June 30, Professor Shaoul Ezekiel was appointed Director of the Center for Advanced Engineering Study, which will become the focal point for continuing education in the School of Engineering. Its goal is the development of new modes of continuing education on a cooperative basis between the Institute and industry. The concepts, that continued success in engineering requires a lifetime of learning, of joint development of subject matter and delivery systems, and of the workplace as a center for learning and working, are all central to the Center's program for broadening and for assurance of lifelong competence and currency of the individual engineer.

Professor David H. Marks was named Head of the Department of Civil Engineering replacing Professor Joseph M. Sussman. Following a six months sabbatical leave, Professor Sussman assumed the position of Director of the Center for Transportation Studies.

Professor Eugene E. Covert was named Head of the Department of Aeronautics and Astronautics, replacing Professor Jack L. Kerrebrock, who became Associate Dean of Engineering.

JACK L. KERREBROCK  
GERALD L. WILSON

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## Department of Aeronautics and Astronautics

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A major change in the Department of Aeronautics and Astronautics has been the promotion of Professor Jack L. Kerrebrock to Associate Dean of Engineering, an appointment from which the School of Engineering is sure to benefit. More recently, the appointment of Professor Shaoul Ezekiel as Director of the Center for Advanced Engineering Studies, has caused another a serious loss for the department. The leadership in teaching, research and departmental activities these men provided will be missed. We wish them good fortune in their new activities.

Professor R. H. Miller, Head of the Department from 1968 to 1978, and the Slater Professor of Flight Transportation, retired on July 1, 1986. His enthusiasm and vitality belie his age. His advice was widely sought and freely given. We are pleased he plans to remain active during the next year in Emeritus status. Associate Professor Robert V. Kenyon left the faculty as of July 1 as well, to join the faculty at the University of Illinois. His departure leaves a gap both in our teaching and research programs in the Man Vehicle Laboratory.

We are pleased to note that Associate Professor Alan H. Epstein was awarded tenure effective July 1, 1986. Assistant Professors Paul A. Lagace and Bruce K. Walker were promoted to the rank of Associate Professor, also effective July 1, 1986.

Dr. Michael Giles accepted our offer and joined the faculty on July 1, 1985. He came to our graduate school from Cambridge University and became a valuable asset at the Gas Turbine Laboratory. He will continue his research in aerodynamics of axial flow compressors and turbine using modern computational techniques.

Dr. Daniel Hastings resigned from the Oak Ridge National Laboratory and also joined our faculty on July 1, 1985. He was applying transport theory to problems associated with fusion energy devices. His interest in physics of rarified gases, including the interaction of rarified fluids of molecules and ions with immersed bodies will allow growth in the study of spacecraft charging and other space environmental problems.

Dr. Mark Drela accepted our offer and joined the faculty on January 1, 1986. Assistant Professor Drela is well known for his design of the Monarch, a high speed man-powered airplane. He was part of the group of Department graduate students that built this aircraft, which set a speed record and won the Kremer Prize from the Royal Aeronautical Society. Professor Drela plans to apply the discipline of computational fluid dynamics to the study of helicopter rotor-wake interaction.

We are pleased to have these men on our faculty.

As of July first the Department faculty consisted of 22 full professors, six associate professors and ten assistant professors. The total is well below that contained in our long range plan, but is but slightly below the complement assigned in the new manning table published recently by the Dean of Engineering.

Last fall a Departmental Teaching Consultant's Group was established. This group consists of Professors Witmer, Walker, McCune and Elias. Each of these faculty members has earned a reputation for exceptional teaching. By virtue of its experience, the group is a valuable asset for young, inexperienced teachers, and also serves as a sounding board for our more experienced faculty who are coping with larger class sizes. They also use the group for suggestions on working more effectively with successive generations of Teaching Assistants.

Last year in this report we indicated there was a desire from some of our graduates and undergraduates to start a new man-powered aircraft project. The goal was to determine the feasibility of a flight from Crete to mainland Greece, in the spirit of the flight of Daedalus. Initial funding was obtained from MIT and the National Aeronautics and Space Museum. The group, including physiologists from the Yale Medical School, under the supervision of John Langford and Mark Drela, determined that such a flight is marginally possible. The results of their study provided encouragement to plan the next step: building a prototype to validate the principles underlying the feasibility study. Sufficient funding has been obtained to start construction of the prototype. We plan to continue the fund raising and hope to fly the prototype by the end of the summer. Professor Kerrebrock's continued commitment to this project has been an important factor in reaching its present state of development.

The goals of the project include a review of the Daedalus mythology in the context of modern technology. Daedalus is considered by some scholars of Greek Mythology to have been a synthesis of

several early engineers. Thus, we now have an exciting project involving faculty and students of engineering, of physiology and human performance, and of the Classics. The interactions between these diverse groups of scholars is valuable to all.

Extracurricular activities like the Daedalus project provide our students an opportunity to be involved in the design, construction and operation of reasonably sized vehicles. This adds a realistic flavor to their education. Employers have been very interested in those students who have participated in student projects of this kind. We have received glowing reports on the progress of alumni who had been involved in such projects. This year members of the Department have been involved in investigating the role of the computer in undergraduate education.

Professor Baron and his associates conducted a survey of the current and future use of computers in industry. Their goal was to determine whether or not industrial use of computers should cause a revision of our course of study. The conclusion was clear. Industrial management believes that it is more important for newly hired engineers to have a good grasp of the fundamentals of physics and chemistry. The representatives of industry did not feel current subject matter should be removed from our course of study and replaced by computer subjects. There was a strong feeling that newly hired engineers should be able to use a computer at the level associated with programming homework problems, and using the program to solve these problems. This conclusion did not apply to Computer Science Engineers or to Ph.D. students who are specialists in Finite Element Methods for Structure Analysis, in Computational Fluid Dynamics, or other forms of discrete or semi-discrete analysis. This view from industry supports the long held hypothesis about undergraduate education at MIT: a good grounding in fundamentals is the best preparation for a long, productive career in engineering.

The Department has also been deeply involved in Project Athena. Several different styles of teaching have been explored by members of the faculty. Professor McCune is using Lagrangian techniques to illustrate features of streamline and streakline flows. Professor Baron has prepared a well documented module illustrating effects of scale in fluid mechanics. Professor Murman has developed a module that illustrates the effects of geometry on aerodynamic loads for a variety of shapes. He and Professor Drela have prepared a new subject to be offered in conjunction with 16.84, Preliminary Design of Aircraft. The new subject is based on Professor Murman's Athena module and is called 16.04 Aerodynamics of Flight Vehicles. Professor Crawley has prepared an "Athena Supplement" which is used with 16.20 Structural Mechanics. In addition to these examples and to our earlier uses of computers in education, we are using computers to manage some parts of experiments in our Project Laboratory.

We feel that we are applying the guidelines of Project Athena not only to explore the possibilities of enhancing education by the use of computers for homework, but also to improve the quality of learning by students as well.

This has been a satisfying year for those members of the Department who conduct experiments associated with space flight in the Space Shuttle. Professor L. R. Young and his group in the Man Vehicle Laboratory were deeply involved in the Spacelab-2 experiments. These experiments were conducted in October in Shuttle Flight 51-G. Compared with Spacelab-1, the time in orbit was very productive because the data was transmitted in real time to the Operations Control Center. This allowed Professor Young and Dr. Oman to modify procedures when so indicated by the data. The range of circumstances covered by the modified experimental procedures was much broader than originally planned and the results were enhanced accordingly. Thus Young and Oman were able to demonstrate under operational conditions a quantitative relationship between symptom intensity (i.e. nausea and disorientation) and head movements.

Professor David Akin flew his experiment about six weeks later on Space Shuttle Flight 61-B. His experiment was designed to determine the productivity of astronauts assembling large structures in space. We believe the Experimental Assembly of Structures by Extravehicular Activity (EASE) was the first experiment of its kind in which flight certified hardware was designed and built by students. The faculty of the Department takes great pride in this achievement by the Course XVI students. Preliminary results suggest that a scaling procedure, developed Professor Akin, allows quantitative simulation of Extravehicular Activity (EVA) in a Neutral Bouyancy Facility. This is a new and significant result. It allows EVA procedures to be developed on the ground where it is much less costly and more efficient than in orbit. Further, quantitative measures of productivity measured in the neutral bouyancy chamber were confirmed in EVA. The confirmation of high rates of productivity in orbit allow more effective planning for future Extravehicular Activity.

Finally, a word of praise is in order for Professor Markey and the Department's Safety Committee not only for an aggressive and successful waste disposal program, but for addressing this problem by educating users of solvents and other chemicals to make safer selections at the time of purchase.

In at least one respect this was a year of continued growth. Both the undergraduate and the graduate enrollment continued to increase. The enthusiasm and freshness of the point of view of these talented young people is infectious. The faculty responds positively to these young people, in spite of the increased work load they represent.

#### UNDERGRADUATE PROGRAM

The continued growth of the undergraduate program reflects the strong national interest in aeronautics and astronautics. This growth over the last seven years is shown in Table 1.

Table 1

	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86
Sophomores	70	78	91	86	100	99	106
Juniors	47	70	73	86	81	90	92
Seniors	41	55	62	85	81	93	106
Totals	158	203	226	257	262	282	304

Approximately 24 percent of the undergraduates are female, and 76 percent are male.

Some years ago the effect of overcrowding in the Project Laboratory was reduced in severity by making the projects larger and assigning two students per project. The consequence was that the students had to learn to plan and work together. We felt this was beneficial. As discussed in last year's report, we have enlarged the shop facilities in an attempt to meet the increasing demand. This seems to meet the short-term need, but it is not a satisfactory long-term solution to this problem of facility saturation. The continued growth in enrollment is also eroding the buffer between the use of laboratory space in the Project Laboratory and the laboratory exercises in Unified Engineering.

We have been able to alleviate some of the loss in educational value resulting from large laboratory groups by increasing the UROP activity. This also has the effect of spreading the laboratory instruction over a wider base. There are other beneficial consequences such as improved faculty/student relationships. However, this mode of instruction, too, is rapidly approaching saturation.

At the present time, the enrollment in Unified Engineering has reached a level where we have reduced the number of experiments and increased the size of the group of students to the maximum extent possible. In other words, any increase in group size will reduce the experiment to a mere demonstration for most of the group. Further, because of the large number of groups, the experimentation for most groups is no longer synchronized with lecture material. Thus some of its educational value is lost. We are addressing this problem in our undergraduate education to insure the quality of education is not reduced by the current large enrollment.

About one-third of our faculty are involved with the freshman program in one way or another. We are told this is a relatively high fraction. It is another indication of the interest of our faculty in the education of undergraduates.

#### GRADUATE PROGRAM

The enrollment of graduate students has also continued to increase. The total number is now up to about 223. Beginning next year the number of offers of admission will be reduced. Our goal is to reduce the number of graduate students by about 20 percent over the next five years in order to bring the average ratio of graduate students to faculty to just over five as compared to its present value of just under six.

#### FACULTY NOTES

Professor Richard H. Battin was the 12th von Karman Lecturer for the Israel Society of Aeronautics and Astronautics.

Professor E. F. Crawley gave invited lectures on "Space Structural Dynamics" at both the Beijing School of Engineering and the Space Research Institute in Moscow.

Professor Eugene E. Covert was elected a Fellow of the American Association for the Advancement of Science.

Assistant Professor Steven Hall was appointed Boeing Assistant Professor of Aeronautics and Astronautics.

Professor Norman D. Ham was awarded US patent 4,519,743, "Helicopter Individual Blade Control System".

Assistant Professor John Hansman has been named a "Presidential Young Investigator", with an accompanying discretionary research award of \$250,000 over the next five years.

Professor Marten Landahl was elected to the Royal Academy of Science of Sweden.

Professor T. H. H. Pian has been elected an honorary member of the American Society of Mechanical Engineers.

Professor Leon Trilling is in charge of the MIT Second Summer Program for 32 Freshmen.

Assistant Professor Lena Valavani has been appointed Associate Editor for two publications: IEEE Transactions of Automatic Control, and Automatica.

Assistant Professor Andreas von Flotow was awarded a \$200,000 Department of Defense Instrumentation award.

Professor Shelia E. Widnall was appointed Mauze Professor of Aeronautics, and was elected President of the American Association for the Advancement of Science.

#### BOOK NOTES (Released this year)

Professor Battin: Introduction to the Mathematics and Methods of Astrodynamics

Professor Covert: ed. Thrust and Drag, Its Measurement and Prediction

Professor Landahl: Turbulence and Random Processes in Fluid Mechanics (with E. M. Mollo-Christenson)

#### OTHER MATTERS

Professor Covert was appointed Department Head, September 1, 1986.

Professors J. W. Mar and A. R. Odoni were on well deserved sabbatical leaves this year.

Professors Emeriti Morton Finston, John F. McCarthy, Jr., and Shatswell Ober died during the last twelve months.

EUGENE E. COVERT



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## Department of Chemical Engineering

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The world of chemical engineering is changing rapidly. Many new technologies are on the verge of take-off, and many new scientific concepts and tools are waiting to be developed and exploited. Many mature industries are no longer competitive, and many mature research areas are no longer providing exciting and challenging problems for investigation. The Department is positioning itself for these changes by acquiring new faculty with the appropriate intellectual backgrounds, developing new research programs, applying new tools to rejuvenate traditional problems, and continuously revising the educational programs.

The job market and the enrollment of undergraduates have more or less stabilized. A high percentage continues to go on to the graduate schools. The graduate student population continues to be at the 210 level. With the nationwide downtrend of undergraduate population in chemical engineering, the supply of first rate U.S. graduate students is expected to decline.

The Department is continuously revising its curriculum to prepare students for this changing world. Mastery of computer methods should be extended from the entry level course 10.01 to the upper level courses; safety in the laboratories and in design courses should be strengthened; and the science base should be broadened to include understanding of macromolecules, complex fluids and solids. These would be very challenging tasks, especially since the Humanities and Social Sciences contents of the undergraduate education are also scheduled to increase. The funding of the Undergraduate Process Laboratory, 10.27, has been concluded successfully, and half of the new experimental equipment is now in operation. A new course in the disposal of toxic wastes was developed, using a great deal of computer simulation as instructional tools.

An area of growing importance is in the cradle-to-grave stewardship of toxic chemicals--alternative pathways and plants to minimize toxic chemical production and leakage, environmental impact of power plants, and disposal of toxic chemicals by incineration and wet oxidation. This area is important for the public acceptance of the chemical and allied industries as responsible neighbors. The development of a leadership position in the research and education of chemical engineers to deal with these problems is a big challenge.

### UNDERGRADUATE PROGRAM

The following table shows the trends in undergraduate enrollment:

	<u>81-82</u>	<u>82-83</u>	<u>83-84</u>	<u>84-85</u>	<u>85-86</u>
Sophomores	127	133	59	61	49
Juniors	104	112	105	47	69
Seniors	<u>111</u>	<u>111</u>	<u>116</u>	<u>115</u>	<u>54</u>
Total	342	356	280	223	172

Freshmen interest in our introductory chemical engineering courses and a stable job market indicate that sophomore registration for 1986-87 will probably be around 50. A level of 60-80 sophomore registration is approximately optimum.

The introductory subject, Engineering Concepts and Computer Methods (10.01), has been integrated into our curriculum. This subject introduces the basic concepts of energy and material balances, thermodynamic equilibrium, rate phenomena and process flowsheeting, and acquaints the students with the vast computing capacity of Project Athena. The Undergraduate Process Laboratory (10.27) is now well established and well received by the students.

Our sophomore thermodynamics sequence (10.13 and 10.14) has been completely revamped to include greater emphasis on the molecular behavior of matter. Quantum mechanical concepts are introduced, and the connection is made between molecular behavior and the macroscopic properties of matter. The macroscopic applications of the First and Second Laws of Thermodynamics are covered more rapidly, building on the material covered in 10.01.

To meet the challenge of "design creativity," the Process Design Course (10.36) was restructured by Professor George Stephanopoulos in order to include modern concepts stemming from systematic methodologies in engineering design. The 41 students carried out, individually or in groups of two, a series of design projects which allowed them to practice the notions of decomposition in design, evolutionary design, identification of key design variables, hypothesis testing and assertion of

intermediate goals, generation of promising alternatives, subjective resolution of design tradeoffs, etc. Within the scope of design methodology, the course attempted to integrate all previous educational backgrounds in chemical engineering science. For the next year, the effort is aimed at providing the course students with the software environment on the Athena system, which will enhance their creative abilities.

#### GRADUATE PROGRAM

The following table shows graduate enrollment from 1981-1986.

	<u>81-82</u>	<u>82-83</u>	<u>83-84</u>	<u>84-85</u>	<u>85-86</u>
Masters	145	93	75	77	72
Doctoral	<u>85</u>	<u>115</u>	<u>132</u>	<u>127</u>	<u>148</u>
Total	230	208	207	204	220

The total for 1985-86 includes 60 foreign students, 33 female students, and 4 minority students (not including Asian Americans). The increase in the total number of students is primarily due to the increased number in the doctoral population. A growing number of students come here to obtain a doctoral degree instead of a master's degree. Thirty-seven of the 54 first-year graduate students passed the doctoral qualifying examination this year, with several more students from this class expected to complete the examination next fall.

Three new graduate level subjects were offered this year. Professor George Stephanopoulos was one of several faculty members responsible for 10.28J and 10.29J, Multivariable Control Systems I and II, which involved the analysis and design of multivariable feedback control systems. Professor Robert Armstrong offered 10.515, Polymer Fluid Mechanics, which covered kinetic theory and rheology of polymer solutions and melts.

The Department also introduced a course on the alternative technologies for treating hazardous wastes taught by Dr. Michael Modell.

#### John von Neumann Center for Scientific Computing

The Department has been heavily involved with the establishment of the John von Neumann Center for Scientific Computing (JVNC) at Princeton, New Jersey, which is fast becoming a general resource for the entire MIT campus. The JVNC is sponsored by a grant from the National Science Foundation. Professor Robert A. Brown serves as one of two MIT trustees for the Consortium for Scientific Computing (CSC), which operates the center and is chairman of the Technical Advisory Committee of CSC. A high speed (1.5 megabytes per second) link between JVNC and MIT is currently in place and approximately 50 accounts on the CYBER 205 supercomputer have been given to MIT faculty. Professor Ulrich Suter of the Chemical Engineering Department has used this resource for intensive computations of polymer confirmation.

#### Laboratory for Biochemical Separation Processes

During the past year a new laboratory for Biochemical Separation Processes was established within the Department under the direction of Professor Charles L. Cooney, Professor of Chemical and Biochemical Engineering. This Laboratory includes a pilot scale fermentation and recovery facility as a focal point for research and teaching in separations chemistry, process control, and integration of fermentation and recovery processes. Alfa Laval, a primary supplier of separation equipment to the biochemical process industry, has provided the funding for this project through a major contract. This contract includes a commitment to provide major equipment for research, renovation of space, and five years of funding for research in biochemical separation problems. The program provides the Department and the recently established Biotechnology Process Engineering Center (BPEC) with a unique facility to teach laboratory techniques at the undergraduate and graduate level with process scale equipment, and to do research in a facility closely representing the "real world" of biochemical process industry.

#### Biotechnology Process Engineering Center

The Biotechnology Process Engineering Center (BPEC) has made significant progress during its first year. The BPEC administrative offices are now centrally located in Building 20A. Twenty-six research involving 18 faculty members from the Departments of Chemical Engineering, Biology, Applied Biological Sciences, Electrical Engineering and Computer Science, and Nuclear Engineering, were established. Through the Undergraduate Research Opportunities Program (UROP) at MIT the BPEC extended research opportunities in biotechnology to support 37 UROP positions. In addition, 37 graduate research assistants, 9 post-doctoral research associates, and 12 research and support staff from the five departments are associated with the activities of this Center. Three biotechnology-related "short courses" were presented during the summer with a total of 250 representatives from industry attending.

The first BPEC symposium was held in October with over 500 people attending. The Biotechnology Process Engineering Center Consortium was established. Twenty-seven companies have joined and 10 additional companies have expressed a positive interest in joining. A Mini-Symposium/Workshop for Consortium members, entitled "Animal Cells: Science and Technology," was held in June.

#### Program in Polymer Science and Technology

The Program in Polymer Science and Technology (PPST), an interdepartmental program with faculty from the Departments of Chemistry, Material Science and Engineering, Mechanical Engineering, and Chemical Engineering will have seven graduate students in its initial class entering in the fall term, three of which will enter MIT through the Chemical Engineering Department. A grant of \$2M was awarded to PPST and the Department of Materials Science and Engineering by the IBM Corporation for faculty and student support and the purchase of equipment. A Polymer Seminar Series was also initiated during the year with approximately 25 guest speakers. Using funds obtained from the Dean of Engineering's curriculum development program, PPST engaged in extensive curriculum development for its core curriculum, taken by all students in the program. Advanced level elective subjects, including an offering in the Department of Physics, are also being developed.

#### The Practice School

Thirty-four students received a Master's degree in Chemical Engineering Practice last year. About 40 percent of these students continued on to our doctoral program, while the remainder was equally distributed between MIT undergraduates enrolled in our 5-year program and Master's candidates originating from undergraduate institutions other than MIT. This year four stations were operated: One in Albany, New York with General Electric at its Noryl plant in Selkirk and its Silicones plant in Waterford; another in Bethlehem, Pennsylvania at the Bethlehem Steel Company; the third in Houston, Texas with NL Treating Chemicals; and the fourth in Upton, New York at the Brookhaven National Laboratory. Assistant Professor Christopher Guzy was the Director at the Albany Station, while Assistant Professor Robert Sproull directed both the Bethlehem and Brookhaven Stations, with Assistant Professor Robert Hanlon running the Houston Station. This coming year we plan to open a new station at Dow Chemical's facility in Midland, Michigan while the Bethlehem Station is temporarily closed.

As the Practice School enters its 70th year of operation, the program continues to represent MIT's unique contribution to internship education in chemical engineering at the graduate level. With its project work conducted at industrial field sites, the Practice School exposes young engineers to the evolving needs of our industry in developing their technical, communication, and managerial skills. The program's health and vitality is strongly influenced by our ability to provide financial aid to its students. Because industrial project work replaces a normal research thesis, the traditional academic method of funding research from government agencies is not appropriate for supporting Practice School students. The companies hosting the field stations provide aid to students while they are in residence, but the Cambridge course work portion needs financial sponsors. Presently we are asking companies to sponsor fellowships at a commitment level of \$15,000 per year.

The Phase II fund raising drive for the Practice School has successfully secured the support of 12 sponsoring companies. Thus, we are approximately halfway toward reaching our goal of \$400,000 per year of fellowship aid committed for the next three years. Alumni support in the form of endowed fellowships is also being pursued.

#### RESEARCH

Combined interdisciplinary and departmental research for which Department faculty were responsible totaled approximately \$9.7 million in 1985-86, compared to \$6.6 million in 1984-85 and \$6.1 million in 1983-84. The research volume generated by the Department alone was approximately \$3.4 million compared to \$3.3 million in 1984-85 and \$2.8 million in 1983-84.

This year's significant increase in the research volume is mainly attributable to the Department's major participation in the new NSF Biotechnology Center.

#### FACULTY AND STAFF

Associate Professor Herbert H. Sawin received permanent tenure in May 1986.

Assistant Professor John F. Brady left the Department to join the California Institute of Technology as an Associate Professor with tenure.

## HONORS AND AWARDS

Professor Janos M. Beer has been elected Honorary Member of the Hungarian Academy of Sciences.

Professor Howard M. Brenner received the William H. Walker Award of the American Institute of Chemical Engineers. Professor Brenner was the Matthew van Winkle Lecturer at the University of Texas, Austin.

Professor Robert A. Brown was the Berkeley Lecturer at the University of California. He also served on the Editorial Board of the Journal of Supercomputer Applications.

Professor Charles L. Cooney received the James M. VanLanen Distinguished Service Award from the Division of Microbial and Biochemical Technology of the American Chemical Society.

Professor Hoyt C. Hottel gave a series of six lectures in Beijing, China.

The International Combustion Institute established the Hoyt C. Hottel Plenary Lecture to be given on the first day of the Institute's biennial symposia, and Professor Adel Sarofim is the first Hottel Lecturer.

Professor Edward W. Merrill was appointed Visiting Professor of Surgery, Department of Surgery, at the University of North Carolina, Chapel Hill.

Professor George Stephanopoulos received the Curtiss W. McGraw Research Award of the American Society of Engineering Education. Professor Stephanopoulos was the speaker at the dedication of the "Leon Lapidus Room," at Princeton University.

Professor Ulrich W. Suter was elected to the Editorial Advisory Boards of Macromolecules and Journal of Polymer Science: Chemistry. Professor Suter's book, Selected Work of Paul J. Flory, three volumes, with L. Mandelkern, J. E. Mark, D. Y. Yoon, was published by Stanford University Press.

Professor Daniel I. C. Wang was elected to the National Academy of Engineering. He was also appointed to the Chevron Professorship, to be held for five years.

Professor James Wei received the Warren K. Lewis Award for Education from the American Institute of Chemical Engineering. Professor Wei served as President of the International Symposium on Chemical Reaction Engineering.

Several Institute-wide honors were awarded to our undergraduates. Karen Lee ('86) was co-winner of the Association of MIT Alumnae Award for the highest level of academic excellence. Karen was also elected to Phi Beta Kappa. Lisa Vingerhoet ('88) received one of the three Eastman Kodak Scholarships awarded in the School of Engineering. Seven students were elected to Tau Beta Pi. Those so honored were Paul Dimilla, Robert Satcher, and Mei Wang, all of the Class of '86, and Nancy Chang, Reid Steinmetz, Maria Tsiakkas and Randolph Wei of the Class of '87.

Departmental undergraduate awards went to Karen Lee ('86), Gina Buccellato ('86), Robert Satcher ('86), Thomas Eccles III ('86), Maria Tsiakkas ('87), and Farzan Riza ('87). Karen received the Roger de Freiz Hunneman Prize in recognition of outstanding scholarship. Gina was awarded the Robert T. Haslam Cup for outstanding professional promise. Robert received the American Institute of Chemists Award for scholarship, leadership, character and promise of advancing the profession. Tom was awarded the Chemical Engineering Department Special Service Award for unselfish contribution to the success of Departmental activities. Maria was chosen for the Dow Chemical Outstanding Junior Award for achievement in scholarship, leadership, and campus activities. Farzan received the AIChE Annual Chapter Scholarship Award for the highest scholastic performance through the first two years.

Graduate students receiving Departmental awards were Alexandra Astill, Beth Junker, Peter Ludowicz and Paul Mikesell. Alexandra was chosen for the Rosemary J. Wojtowicz Memorial Prize in Chemical Engineering Practice for exemplary performance, integrity and commitment to the Practice School program. Beth received the Departmental Special Service Award for unselfish contribution to Departmental activities. Peter and Paul were chosen to receive the Outstanding Teaching Assistant Award on the basis of their contributions to the Departmental teaching program.

Professor Jefferson Tester was chosen to receive the Outstanding Faculty Award for excellence in teaching and research. Arthur Clifford and Charles Foshey received the Outstanding Employee Award for their work with the students in support of the research program.

JAMES WEI

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## Department of Civil Engineering

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### INTRODUCTION

This was a year of transition in the leadership of the Department. On September 1, 1985, Professor David H. Marks, a member of the Water Resources and Environmental Engineering Division (WREE) of the Department, took over as Head from Professor Joseph M. Sussman. Professor Sussman had served five distinguished years during which time he worked with the faculty to develop new initiatives in the computer, construction, technology, intelligent systems, infrastructure, offshore engineering and materials areas. As we have noted in our Five Year Plan submitted to the School of Engineering last fall, the evolutions of these areas, plus that of hazardous waste management, are still and will continue to be the central core of the Department's focus. Thus while there has been a change in leadership at the top, our underlying philosophy along with the commitments for change made by our faculty has not changed. The opportunities for new directions in research and education in civil engineering have never been better. Driven by pressing problems in environmental control, the need for engineering and construction productivity increases, the search for and extraction of natural resources, and the provision and rehabilitation of infrastructure, the profession will go through a considerable metamorphosis in the next ten years. The Department is, we feel, well prepared and well positioned to provide leadership for that change. As you will see in the following sections, concrete evidence in terms of new programs, new research support, and new initiatives is already at hand and our momentum is increasing.

### Undergraduate Education

This year the Department has brought about a major change in its undergraduate program to help in preparing students for our view of the profession. Previously our program had focused on a common sophomore year unified core of basic materials in solid mechanics, economics, fluid mechanics, systems, and probability. Then a student, in junior year, chose a specialty area in constructed facilities, water and environmental engineering, or transportation systems. We have moved to stop this diversification in the junior year by presenting a junior core with materials in soil mechanics, structural engineering, fluid dynamics, and ecology, for all those in our designated program. We have added major subjects as well in computation within this program. We will also present an undesignated option, Course IA, focusing on Engineering Systems and Computation (ESC). This option is designed for students who wish to have a broad based systems and computation program but do not wish to satisfy all of the requirements for the S.B. in civil engineering. The program is focused on software and system analytic tools for dealing with large and complex engineering issues. It prepares students for careers in diverse fields such as engineering model building, engineering application of robotics, automation in large scale systems, and data acquisition and handling. The ESC option lays a general engineering systems and computation basis for people who want to pursue graduate studies in fields such as business management; operations research; planning; engineering project management; as well as further study in application areas such as transportation, energy, the environment, and logistics. Both programs will be put into effect in September 1986.

Our teaching program continues to provide service subjects for the Institute as a whole. Subject 1.00 Introduction to Computer Systems is a popular subject with an enrollment of over 200 undergraduate students per year. We have also taken over responsibility for the School of Engineering's school-wide Subject 1.12 Computer Models of Physical and Engineering Systems. New initiatives in Institute service subjects in the environmental, ecology, and systems areas are also being planned.

### Graduate Program

#### Center for Construction Research and Education (CCRE)

The Center was formed in 1982 as a cross-department program under the direction of Professor Fred Moavenzadeh, aimed at interaction with the construction industry. This year the Center's educational program continues to attract large numbers of well qualified graduate students and continues to produce unique, well trained professionals for the industry and a cadre of new research oriented Ph.D.'s who are helping to refocus construction activities in academia in the US and around the world. New subject development for the Center has focused in areas of innovative technologies that have a strong coupling with the research interest of the Department's faculty. For example, in the area of Process Technology, Dr. Kenneth Maser is expanding his successful subject in automated in situ sensing and condition assessment of large scale infrastructure. Professor Marks and Mr. Michael Markow have developed a major Subject 1.44 Analysis Methods in Infrastructure Renewal. Professor Lorna Gibson has developed a subject 1.592 Mechanical Behavior of Construction Materials and is working on another on composite materials for construction. Professor Jerome Connor presented a subject on Knowledge Engineering during the fall term;

Professor Duvvuru Sriram, a new faculty member, presented a spring semester subject on Building Knowledge Based Systems for Engineering Problem Solving, and two other faculty members, Professor Robert Logcher in the area of project control, and Professor John Slater in the area of computer aided structural design and engineering, are developing subjects which incorporate knowledge based expert systems. Dr. Y. Rosenfeld, a Visiting Assistant Professor, from the Technion, Israel, will continue an extra year teaching his popular subjects in construction productivity and technology. Professor Alex Slocum, another new faculty member, has developed and taught a new subject on design for construction automation..

#### Transportation Systems Division (TSD)

Under the leadership of its new Division Head, Professor Yosef Sheffi, the Division spent considerable time in exploring its mission and goals. During a series of meetings, the Division recognized that its focus and its traditional strength are in transportation systems analysis. This includes both the application of fundamental methodologies (such as operations research, econometrics, computer science, and engineering economics), and the development of specific transportation-related methodologies (such as discrete choice analysis, network equilibrium models, routing and scheduling algorithms, and interactive optimization tools). The following areas will receive concentration: logistics and carrier operations; transportation infrastructure; and urban transit planning; while recent activities in the areas of policy and institutional analysis will be deemphasized due to faculty losses in these areas which we have chosen not to replace. The Division went through a massive restructuring of its graduate subject contents to broaden its offerings wherever possible to attract more students and offer a service to the MIT student community at large. In addition, subject content was upgraded to include more computer applications and made more rigorous where necessary. A concerted drive in the spring of 1986 has led to a 40 percent increase in Division students for fall 1986 while maintaining excellent student quality. In addition, several of the basic TSD courses already experienced a large increase (100 - 300 percent). We are pleased by the excitement and renewed vigor of this program.

#### Constructed Facilities Division (CFD)

Lead by its Division Head, Professor Gregory Baecher, the Constructed Facilities Division is also grappling with a major overhaul of its graduate program. The existing program evolved within the earlier context of CFD research and professional activities around the two nodes of structural engineering and geotechnical engineering. These foci have changed as the profession and our research directions have changed, yet the education program has not kept up with this. During the coming academic year the principle objective of the Division is to rethink the graduate program at a fundamental level and develop a new or recomposed curriculum. A key contribution from CFD this year has been its strong educational input into a variety of new initiatives in the Department. Through better integration with CCRE it is providing the leadership in construction systems, technology, and materials. It is also heavily involved in providing leadership in the School of Engineering's major initiatives in rebuilding laboratory facilities (the REMERGENCE Laboratory, Resource Extraction, Materials and Energy, Reservoir, Geotechnical, Environmental, and Construction Engineering, facilities).

#### Water Resources and Environmental Engineering Division (WREE)

The Division, under the leadership of Professor Rafael Bras, continues to experience high demand with excellent applications. It is reviewing its doctoral programs, in particular the nature of the general examination for entrance to the program. New subjects in mathematical modeling, groundwater modeling, and experimental methods in hydrodynamics, have been introduced. New link ups with Project Athena have been established and there are several book projects in the works: Professor Philip Gschwend on "Organic Contaminants", Professor Michael Celia on "Numerical Modeling of Groundwater Transport", Professor Donald Harleman on "Transport Processes in Environmental Engineering", Professor Bras on "An Introduction to Hydrologic Science", and Professor Lynn Gelhar on "Stochastic Analysis of Groundwater Flow and Transport".

#### Program Development

In this year's report we highlight major new program development initiatives; each of which has broad implications for the future direction in our Department:

##### 1. US Army Support for Construction Activities

In the fall semester, CCRE successfully negotiated four indefinite delivery contracts with the US Army Construction Engineering Research Laboratory (CERL) to provide specific support for the Army civil facilities construction area. Professor Marks is Principal Investigator. As of June 30, 1986, twelve Task Orders, valued at almost \$700,000, have been initiated.

Early in 1986 the Department submitted a proposal with Professor Moavenzadeh as Principal Investigator, for a \$15 million five year funding for a US Army Research Organization, University Research Initiative

Center for Advanced Construction Technology. The proposal offered new research in areas such as construction robotics and automation, intelligent construction computer systems and new materials and technology for construction. We have just been notified that our proposal has been accepted with final budget negotiations to take place in late July for a September 1986 start. This is important news not only for the funding in an area which traditionally has received little support, but it also shows that our message of the need for the entire construction industry (contractors, owners, materials suppliers, the financial community, the regulatory community) to focus on joint problems of technologic innovation is finally being heard. We expect to have many more owners and contractors joining the Army in this consortium in the near future to help define and focus, as well as fund, the vital work that needs to be done to revitalize the construction industry.

## 2. Construction Robotics and Automation

The Construction automation effort, a vital component of our approach to advanced construction technology, gained considerable momentum this year. Two full time faculty are devoted to the program: Professors Baecher and Slocum; and one Research Associate, Dr. Maser. Professor Slocum has expertise in machine design and mechanical engineering. Research support has been generated from the National Science Foundation, the US Army Construction Engineering Research Laboratory, and the private sector, to work on automated machines for commercial building construction and from the Army to work on intelligent non-destructive testing systems for condition surveys and on control systems for construction equipment. New laboratory space in the basement of Building One has been developed for this effort. Professor Slocum offered a new subject this spring in Construction Robotics, which was well attended. Out of this initiative, approximately 25 students have been attracted to the program for thesis work and UROP activities. These are for the most part undergraduate students from outside Civil Engineering coming primarily from Courses II and VI.

## 3. Construction Materials

This program has been gaining momentum for the past three years. There are now 5 faculty members associated with the program -- Professors Oral Buyukozturk, Herbert Einstein, Lorna Gibson, Victor Li, and S. Shyam Sunder -- all within the context of the REMERGENCE Laboratory. Dr. John Germaine and Professor Charles Ladd are also associated with the Laboratory development. Material research within the Department now spans a broad spectrum including cellular materials, ceramics processing, ice, soil, rock and high temperature, and pressure refractory cements. Within the REMERGENCE framework, we are developing a major new cold facility for ice research and expect to add considerable experimental equipment through the new Army Center for Advanced Construction Technology. All of these areas represent major advancements and increases of effort in the last three years. We are now searching for one additional faculty member to complement the existing team by bringing more chemical background to our work.

## 4. Hazardous Waste Management/Groundwater Management

This year the Institute is putting together a major initiative in the area of hazardous waste management that deals with the problem from "cradle to grave." This is described in great detail in the report of the Center for Technology, Policy and Industrial Development (CTPID). The Department is providing overall direction for this activity through the efforts of Professor David H. Marks and Professor Daniel Roos (Director of the CTPID), as well as individual research and educational activities in the ecology, groundwater management, landfill design and monitoring and leaking underground storage facilities area. The Electric Power Research Institute (EPRI) is funding work within the Water Resources and Environmental Engineering Division on macro dispersion experiments including field site work in the migration via groundwater of toxic pollutants from buried fossil fuel residues from power plants. The USGS and EPA are also funding development and involvement of a groundwater contamination site on Cape Cod, Massachusetts. We hope that this will ultimately be recognized as a unique national research site under the aegis of the USGS and MIT. It would appear that hazardous waste problems will now be receiving the long term research support needed to finally address important management issues and the Department is well positioned to take part in these activities. A new faculty member, Professor Michael Celia, whose specialty is in groundwater modeling has arrived this year to help in this effort.

## 5. Infrastructure

The problems of maintaining a vast inventory of rapidly aging highways, bridges, dams, rail links building, and pipelines, is becoming increasingly difficult and costly. Civil Engineering is performing research in every aspect of new materials for repairs, performance standards for existing systems, new technology for in situ and non-destructive testing, and institutional, scheduling, and financing questions. In December 1985, CCRE and CTS received additional funds for establishing the New England Surface Transportation Infrastructure Consortium. This project involves the design and implementation of an organization and program for aggregating the needs and resources of the six New England state transportation agencies, the six state universities, and MIT, and focusing them on integrated regional specific R&D programs. The planning phase of the Consortium has been funded by \$140,000 in grants from

the six states with the expectation that the program will be started sometime in fall 1986 with a funding level of \$1 million per year. Professors Sussman, Roos, and Moavenzadeh, are jointly coordinating the program and Mr. Thomas Humphrey is service as Executive Director. In addition, we have received considerable funding from the US Army Construction Engineering Research Laboratory in the area of maintenance management of large civil systems. A new faculty member, Professor Sue McNeil, whose specialty is transportation infrastructure management, has already made major contributions in this area.

#### 6. Intelligent Engineering Systems

Professors Connor, Logcher, and Slater, continue to provide leadership in our efforts in computer aided engineering and education. They have helped to form a new intelligent engineering systems group for coordinated research and education and have been successful in attracting students and funding. Professor Slater's work in Project Athena on computer aided education in structures is a showpiece of Project Athena and negotiations are going on for technology transfer to other institutions. Professors Connor and Logcher have been working on expert systems and data base problems and applications in engineering with great success. They were joined in April 1986 by Professor Sriram who is a specialist in expert systems applications in civil engineering problems.

In addition to these new developments, the Department's activities in offshore engineering continues to prosper. We have just finished our third year of five funding from SOHIO for a Center of Excellence in Offshore Arctic Engineering. The WREE Division continues to provide substantial input for the MIT/Woods Hole Oceanographic Institute joint program. Professors Sallie Chisholm, Keith Stolzenbach, Francois Morel, Harry Hemond, Philip Gschwend, Ole Madsen, and Kenneth Melville, are all supervising joint program students and carrying out research in the joint program. TSD continues to play a major leadership in the Center for Transportation Studies.

#### Resource Development

This year a tremendous increase in computational resource available to the civil engineering education and research programs has taken place. We have received from Project Athena, a faculty development cluster with five Microvax II workstations in recognition of our central role in that project. These machines are used by those faculty and research assistants supported by Project Athena to do developmental work. The faculty involved in these activities are listed in the Program Development section above. For research, the Department has moved from zero to eight Microvax IIs this year to serve the needs of various research groups. The impetus for this was the decision by the partners (Civil, Mechanical, and Ocean Engineering) to put its centralized joint computer facility out of business due to the advent of new technology that no longer made centralized facilities cost effective.

The Department has also received discretionary funding from the Union Pacific Shell and Exxon Foundations and REMERGENCE Laboratories have been successful in a \$200,000 equipment grant from the ARCO Foundation. Professor C. C. Mei has begun fund raising for a major new three dimensional wave generation experimental facility in the Parsons Laboratory with a \$250,000 grant already in place from the Office of Naval Research.

#### Faculty and Staff

Professor Nigel Wilson, of the Transportation Systems Division, and Professor Amr Azzouz, of the Constructed Facilities Division, were both on sabbatical leave during the 1985-86 Academic Year.

Two resignations were received: Professor Eric Vanmarcke, of the Constructed Facilities Division, resigned to take a position at Princeton; Assistant Professor George Kocur resigned to take a job in industry.

Promotions: Professor Philip Gschwend, a specialist in the fate of organics in the environment, was promoted from Assistant to Associate Professor; Professor W. Kendall Melville, a specialist in experimental and theoretical wave mechanics, was granted tenure; and Professor Sallie Chisholm, a specialist in ecosystem ecology was promoted to the rank of Full Professor.

During 1985/86, Visiting Professors were Professor Avi Ceder from the Technion, Israel, Professor Ronald Scott from Cal Tech; Professor Y. Rosenfeld from the Technion, Israel; and Visiting Scholars were Herbert Klapperich, West Germany; Hang Choi, China; Yuzo Shinogaki, Japan.

Civil Engineering faculty continue to provide a considerable service role to the Institute. Professor Daniel Roos, Japanese Steel Industry Professor of Technology, is Head of the School of Engineering's new Center for Technology, Policy and Industrial Development; Professor Joseph M. Sussman is Head of the Center for Transportation Studies; Professor Fred Moavenzadeh, William E. Leonard Professor of Engineering, Heads the Institute's Technology and Development Program; Professor Richard DeNeufville Heads the Technology and Policy Program, the educational arm of CTPID; Professor Herbert Einstein is Head of the multi-department REMERGENCE Laboratory effort; and Professor Steven Lerman is Head of the



Institute's major computers in education initiative - Project Athena.

Professor Moshen Baligh lectured on "Pile Installation Effects" at the University of Houston Distinguished Lecturer's series. Professor Baligh is also editor of an MIT book entitled "Recent Developments in Measurement and Modeling of Clay Behavior for Foundation Design," in press with Elsevier Science Publishers, Amsterdam, Holland. This grew out of a major MIT short course held during August 5-9, 1985 as part of MIT Summer Session. Other MIT faculty involved were Professors Azzous, Ladd, and Robert Whitman.

Professors Moshe Ben-Akiva and Lerman published a new book Discrete Choice Analysis: Theory and Application to Predict Travel Demand, MIT Press, Cambridge, MA 1985.

Professor Rafael Bras is Chairman of the Journals Board for the American Geophysical Union while Professor Peter Eagleson, Edmund K. Turner Professor, is starting his two year stint as President of the American Geophysical Union.

Professor Gregory Baecher Chaired a Session at the Second International Conference on Construction Robotics.

Professor Michael Celia was Session Chairman at the Finite Elements in Water Resources Conference in Lisbon, Portugal, June 1986.

Professor Sallie W. Chisholm was Co-Convenor of and led Sessions in Flow Cytometry Applications at the American Society of Limnology and Oceanography/AGU Conference in New Orleans, January 1986.

Professor Richard DeNeufville received the Alpha Kappa Psi Award for best paper over the last ten years entitled "Decision Analysis for Optimizing the Choice of Fire Protection and Insurance", Journal of Risk and Insurance, given by the Risk and Insurance Society.

Professor Lorna Gibson was awarded the Esther and Harold Edgerton Assistant Professorship for her work in constructed related materials. She is also the Department Advisor for the student chapter of the American Society of Civil Engineers.

Professor Donald R.F. Harleman was a Session Chairman at the ASCE Hydraulics Conference, Orlando, Florida, August 1985.

Professor Harry Hemond continues as the Department's UROP Coordinator and Supervisor of the Department's UROP Freshman Fellowship Competition.

Professor Charles Ladd has been chosen to give the 1986 Carl Terzaghi Lecture at the 1986 fall ASCE Conference in Boston.

Professor Robert Logcher presented the keynote address on "Automatic Interpretation of Project Data", at the Second International Conference on Microcomputers in Engineering, Swansea, UK.

Professor C. C. Mei was elected to membership in the National Academy of Engineering.

Professor W. Kendall Melville has been awarded a John Simon Guggenheim Fellowship for 1986.

Professor Yosef Sheffi received the Plowman Paper Award from the National Council of Physical Distribution for a paper "Carrier/Shipper Interactions in the Transportation Market", Journal of Business Logistics, June 1986.

Professor Duvvuru Sriram was Technical Chairman of the International Conference on Artificial Intelligence in Engineering, given in April 1986 at Southampton, UK.

Professor S. Shyam Sunder was awarded the Department's Gilbert W. Winslow Career Development Chair in recognition of his achievement in the offshore engineering and ice materials area.

Professor Alex Slocum was awarded the George Macomber Career Development Chair for his work in construction robotics.

Professor Robert Whitman is serving this year as President of the Earthquake Engineering Research Institute.

We are sorry to report that Professor Emeritus John Babcock, age 96, died February 19, 1986. Professor Babcock, an expert in railroad engineering, was at MIT from 1916 to 1954 and remained a staunch and loyal supporter of the Department.

#### Visiting Committee

A Visiting Committee meeting Chaired by Dr. Harl Aldrich, President of Haley and Aldrich Geotechnical Engineers, was held on April 2 and 3, 1986. The Committee was given detailed tours of our experimental facilities in Building One and in the Parsons Laboratory in Building 48 and was fully briefed on our latest initiatives. The discussions that followed were fruitful and incisive and of course helpful to the Department.

DAVID H. MARKS

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## Department of Electrical Engineering and Computer Science

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After two years of declining numbers of sophomore majors in Electrical Engineering and Computer Science (EECS), and in spite of significant efforts to provide attractive alternative programs, the number of Course VI sophomore majors is expected to increase to about 350 next Fall. This number is in contrast to a goal of 270 incoming majors, a number determined by the Department two years ago as being a reasonable load for a somewhat larger faculty than we currently have. The Committee on Undergraduate Admission and Financial Aid (CUAFA) has chosen not to exercise the option, available to it as a result of a vote of the MIT faculty in October 1984, to restrict admission to Course VI for subsequent incoming freshman classes. Instead, it is hoped that a major change in the pool of applicants as well as greater concern for the enrollment issue in the admissions process will make it possible to redress the balance between the enrollments and the existing resources at the Institute. We in EECS are willing to participate in the process of admitting a more balanced class, but we feel that a more stringent policy will be needed if this new approach fails. We note further that, regardless of what happens to future sophomore classes, the Department is now guaranteed relatively high undergraduate enrollments for the next three years.

Our Undergraduate Educational Policy Committee (UEPC) has been discussing possible changes in our undergraduate program, especially in Electrical Engineering (VI-1). These discussions parallel discussions at the School level in the Commission on Engineering Education. At the present time the UEPC has made no definite proposals, but one set of concerns and goals is clear enough to shape future proposals. We wish our undergraduates to have an educational experience at some point in the junior or senior year that a) is very different from the usual lecture/recitation/problem-set format, b) will encourage reading from more diverse sources than a single text, and c) will provide students with a "shared experience" of substantial duration. A year-long seminar on some topics in mathematics or physics related to electrical engineering is one way of accomplishing this goal, although deciding what to give up to make room for it is the difficult question. Another way to achieve the same goal is a year-long design project in which a team of five or six students works with one or more faculty members. This last concept might well be implemented in a manner to satisfy automatically the SB Thesis and Department Laboratory requirements. We hope to find several ways of achieving the stated goals, so that each student can find the most appropriate one.

A major concern about the graduate program in recent years has been the lengthening of the time required to complete it, especially at the SM level. This lengthening has caused an increase in graduate student population. Many of us on the faculty can remember the time when an SM program used to be a calendar year in duration for students who were not teaching assistants. Recently, however, the duration of the average non-VI-A SM program in the Department has become greater than two years, and is nearly three years long in Computer Science. A committee, chaired by Professor Robert Gallager, has been looking into this and related issues and will report in the Fall on suggestions for dealing with this issue. One difficulty in dealing with the length of the SM program is that for the most part, as long as research funds are plentiful, both students and faculty appear to be quite happy to have a relatively long program, particularly for students who are going on to the doctorate anyway.

On the research front we note increasing difficulty in obtaining support in various areas. For example, major reductions are expected in DOE funding for fusion research. We also note that the change in government funding patterns to encourage "centers" has involved our faculty in several large proposals under the DOD's University Research Initiatives. The proposals that were "finalists" in this process were in areas such as high speed electronics, robotics, intelligent control, and manufacturing.

One of the most memorable events of the past year was the naming of Building 39 as the Gordon S. Brown Building. Professor Gordon Brown was head of the Electrical Engineering Department in the 1950's and Dean of Engineering in the 1960's. It is appropriate that Building 39 be named for Professor Brown, because he pressed the administration for the building in order to house the Information Processing Center, the original tenants of the building. The Gordon S. Brown Building now contains elaborate facilities for integrated-system and submicron technology research. The renovation of the building and the purchase of its equipment were the result of a \$23 million campaign by the Institute. Approximately \$9.5 million of this total was donated by twelve companies or company related foundations, most of whom, along with others, continue to contribute operating funds for these facilities.

We have traditionally listed awards at the end of this report. This year we would like to highlight a number of the awards won by our faculty. In recent years, the National Science Foundation annually has named one hundred Presidential Young Investigators in a variety of fields. Four young faculty members in EECS received the award this year. They are Assistant Professors Robert Berwick, James Fujimoto, Roger Howe and John Tsitsiklis. Except for EECS, the most such awards received by a department anywhere in the country was two.

The Department was especially pleased that its faculty have won both of the annual major MIT faculty awards. The Edgerton Award for outstanding achievement by a junior faculty member was given to Associate Professor Jeffrey Lang. Professor Mildred Dresselhaus was chosen to be the Killian Lecturer for the next academic year. Professor Dresselhaus was also named Institute Professor this year, the highest honor the MIT faculty can bestow on one of its colleagues. She is the first woman to be named Institute Professor or Killian Lecturer.

The Department's annual Spring party has been held at Endicott House for several decades. As a result of the larger size of the Department, we have had to find alternate quarters this year. This Spring we held the party at the Museum of Fine Arts. About 500 people attended this successful event, including those of the graduating Course VI undergraduates who were able to accept our invitation, extended this year to our whole graduating class for the first time.

#### UNDERGRADUATE PROGRAM

Enrollment of undergraduates averaged 1,135 in 1985-86, with about 67 percent in the Electrical Engineering Program and 33 percent in the Computer Science Program. The total represents a decrease of about 15 students from the previous year. As a result of a variety of efforts aimed at reducing the number of our undergraduates, 320 sophomores were enrolled in the Department this year. This was down from the 369 students who enrolled in the Department the year before. Unfortunately, initial estimates indicate that a sophomore class of about 350 students will enter the Department in the Fall of 1986, where we had hoped to reduce the number to 270. Although it has been decided not to place restrictions on any admitted students limiting their choice of major, we have reason to hope, from the composition of the 1986 admitted freshman class, that fewer than 310 students will select the Department in the Fall of 1987.

The following prizes and awards were won by our students. The Ernst A. Guillemin Prizes for outstanding S.B. theses in Electrical Engineering were awarded to Saed G. Younis of Kuwait (first prize), John D. Port of Park Ridge, IL, (second prize), and Bovornrat Darakananda of San Francisco, CA (third prize). Honorable mention went to David A. Chanen of Iowa City, Iowa, and Roy I. Vandermolen of Deridder, AL. The William A. Martin Memorial Prize for the outstanding thesis in Computer Science was won by David A. Chanen of Iowa City, Iowa (first prize), and Craig D. Chambers of Reston, VA (second prize). The Computer Systems Thesis Prize was presented to Henry Manyan Wu of Hong Kong (first prize). The George C. Newton Prize for the best undergraduate laboratory project was awarded jointly to Bradley P. Price of Putney, VT, and Fred G. Martin of Woodstock, NY. David C. Martin of La Crosse, WI, was awarded the Honeywell Prize for excellence in engineering. The 6.004 design prize was won by Lawrence Candell of Jericho, NY.

The following special scholarships were awarded to our students: the General Motors Scholarships for academic excellence were awarded to Michelle R. Dick of Greer, SC, and to Mathews M. Cherian of Canton, IL. Jeffrey Y. Pan of Newton, IA, and Ben-Hong Lim of Penang, Malaysia, were awarded Henry Ford II Scholarships.

Thomas T. Huang of Urbana, IL, and Bryan R. Moser of Edgewood, KY, were awarded the Karl Taylor Compton Award for outstanding contributions in promoting high standards of achievement and good citizenship within the MIT community. Lauren F. Singer of Fort Lauderdale, FL, was awarded the Louis Sudler Prize in the Arts. The Laya W. Wiesner Award, recognizing an undergraduate woman who has most enhance MIT community life, was given to Vivienne Lee of St. Louis, MO. William M. Hobbib of Mountainside, NJ and David C. Martin were awarded William L. Stewart Awards for outstanding contributions to extracurricular life.

#### GRADUATE PROGRAM

In September, 1985, there were 630 graduate students enrolled in the Department. Of this number, 210 were newly admitted. About 20 percent of the total were foreign nationals. The Department supported 269 Research Assistants, 121 Teaching Assistants, and awarded 39 fellowships. In addition, there were 37 National Science Foundation Fellows and 12 Hertz Fellows. The remaining students had industrial or foreign government support or were using their own funds.

During 1985, the Department awarded the following graduate degrees: 159 Masters of Science, 27 Electrical Engineers, and 49 Doctorates.

The Department received 1,877 applications for the 1986-87 year. The applicants were generally excellent and 298 were admitted, of whom we expect 198 to register for next Fall.

A number of Departmental awards were made to graduate students for excellence in teaching. Franklyn A. Turbak, of Sandy Springs, CA, received the Carlton E. Tucker Award, while Thomas H. Lee, of LaJolla, CA, received the Harold L. Hazen Award.

Frederick C. Hennie, III Awards were presented to Ann N. Tulintseff of Clinton, MD; Kin-Wai Leong of Kuala Lumpur, Malaysia; Brian M. Oki of Gardenia, CA; Forrest J. Theissen of Littleton, CO, and Ramakrishnan Dundaram of New Delhi, India.

Ann N. Tulintseff, Franklyn A. Turbak, and Thomas H. Lee were awarded promotions to Instructor "G" in recognition of their demonstrated teaching abilities and services to the Department.

#### VI-A INTERNSHIP PROGRAM

The Department's VI-A Internship Program, in its 68th year, continued its popularity with two percent more of Course VI sophomores applying for admission than a year ago, in spite of an announced continuance of a departmental ceiling on the size of the Program. One hundred ninety two applications were received and, of these, the participating companies were able to accept 96. This will bring the total June 1986 enrollment to about 265.

To assist the Department with the administration of this large program, Mr. Kevin J. O'Toole was hired as Associate Director. He commenced his duties August first. His involvement with MIT since 1973, first as Professor of Naval Architecture in Course XIII and later as Technical Officer of the "Technology Adaptation Program" in conjunction with Cairo University, brings an appropriate background to the management of VI-A.

Seven years ago Director Tucker inaugurated holding a summer picnic for students at VI-A companies in the San Francisco Bay area (41 students this year). In the summer of 1985, through Director Tucker's arrangements, this function was joined by the MIT Club of Northern California which helped with the local arrangements. Many alumni also joined the gathering. For 1986 the Club Officers have asked for expansion of participation to include Bay Area freshmen who will be coming to MIT in September, thus incorporating an Educational Council function with the VI-A Internship Program. It is hoped this will give the new freshman earlier direct contact with students currently enrolled at the Institute.

In October Director Tucker presented an invitational talk on "Co-operative Education" to executives and managers at the E. I. duPont de Nemours & Co. (Inc.) corporate offices in Wilmington, Delaware. The company, at that time, was considering a move into co-operative type education.

Unfortunately, the Naval Surface Weapons Center, which had planned to resume its participation of new VI-A's in 1986, was forced to cancel their hiring at the last minute as a result of the Gramm-Rudman Congressional budget restrictions. It is our expectation that NSWC will resume its participation next year.

#### RESEARCH

Most research of our faculty is performed in interdepartmental laboratories. We estimate the total FY86 research volume on projects of which our faculty or research staff members are in charge to be over \$47 million, of which only \$4.5 million takes place under the jurisdiction of the Department. The bulk of the balance is allocated among the following interdepartmental laboratories associated with EECS.

	\$million (estimated)
Artificial Intelligence Laboratory	6.3
Laboratory for Computer Science	12.0
Laboratory for Electromagnetic and Electronic Systems	2.8
Laboratory for Information and Decision Systems	3.2
Research Laboratory for Electronics	8.0
Plasma Fusion Center	10.0

In addition to the laboratories noted above, faculty research is also performed in other interdepartmental or MIT-affiliated laboratories, namely: Energy Laboratory, Operations Research Center, Center for International Studies, Center for Materials Science and Engineering, Lincoln Laboratory, Francis Bitter National Magnet Laboratory, and Biomedical Engineering Center for Clinical Instrumentation (see Health Sciences and Technology (HST) Research Activities). Information on the work of all the interdepartmental laboratories mentioned above appears in other portions of this report, dealing separately with each one. However, the MIT Microsystems Research Center and MIT Stroboscopic Light Laboratory are departmental in organization and therefore report below the highlights of their research for the past year.

#### MICROSYSTEMS RESEARCH CENTER (Professor Paul L. Penfield, Jr.)

MIT research in microsystems is an interdisciplinary, interdepartmental enterprise, started about 1978, and coordinated by the Microsystems Research Center. This year the level of research in microsystems exceeded \$8 million, and the technical areas of interest included electronic materials, submicron structures, integrated-circuit processing and devices, design automation, architecture, and VLSI theory. This research is actually carried out in various other Laboratories, which report on it separately.

During this year, two ceremonies focused attention on the microsystems program. First, the renovations of the building housing the new VLSI fabrication facility were completed, and the building was dedicated in honor of former Dean Gordon Stanley Brown on December 6, 1985. Second, a plaque honoring the companies and foundations that supported these renovations was unveiled on Monday, May 19, 1986, on the first floor of the Brown Building.

A few of the most exciting recent research results in this area were presented in a symposium entitled "Diamonds in the Sand," on the occasion of the dedication of the Brown Building. Seven particular achievements were presented:

- \* UV Write-Enabled PROM. In a normal PROM (Programmable Read-Only Memory), a high-voltage electrical signal sets the memory and ultraviolet light erases it. Professor Lance Glasser invented a circuit in which the UV light enables the writing. The advantage is that no high-voltage signals are used, and therefore standard MOS fabrication sequences can be used. It is now practical to place a modest amount of programmable nonvolatile storage on an ordinary chip.
- \* SCHEMA: Knowledge Based CAD. A VLSI CAD (Computer-Aided Design) frame is a software environment in which various CAD tools can work. SCHEMA, under development by Professor Richard Zippel, is such a frame that features pass-through debugging techniques, coherent and automatic translation of design data between various levels of representations, and a large collection of utility programs to simplify the task of CAD tool designers.
- \* Logic-Level Simulation of VLSI Circuits. A full electrical simulation of a circuit of the complexity encountered in today's VLSI chips is prohibitively expensive. Logic simulation is based on a more abstract model, permitting much more rapid simulation without waveform details. MIT work by former students Randy Bryant and Christopher Terman have produced switch-level simulation, a form of logic simulation appropriate for MOS circuits.
- \* Low Temperature Semiconductor Processes. The high temperatures normally used to fabricate integrated circuits cause smearing out of sharply defined structures, thus limiting how small the resulting devices can be. Professor Rafael Reif has developed low-temperature versions of chemical vapor deposition steps without such effects. Layers of silicon have been grown at temperatures as low as 650°C.
- \* New Ceramic Processes for Microelectronics Packaging. Ceramic packages in use today have structural and electrical features much larger than the features on the silicon chips they support. Professor Kent Bowen has developed a process for firing a ceramic substrate in which all the shrinkage occurs in the vertical direction; the lateral accuracy is therefore much higher. This technique has been extended to include etching of ten-micron-sized features in the ceramic.
- \* Submicron Structures and Quantum-Effect Devices. It is commonly believed that after normal transistors get as small as they can, the next generation of devices will use quantum effects. Professors Henry I. Smith and Dimitri Antoniadis have successfully fabricated and tested devices that display the quantum "super-lattice" effect.
- \* Electron Velocity Overshoot in Ultrashort Channel MOSFET Devices. Typical transistors made today have channel lengths as small as 1 micron. Professors Antoniadis and Smith have made what is probably the world's shortest transistor, with channels only one sixteenth as long, using x-ray lithography. At liquid helium temperatures these devices have exhibited velocity overshoot, a potentially beneficial effect that occurs only in very short devices with very few lattice collisions.

#### Stroboscopic Light Laboratory (Professor Harold E. Edgerton)

The Department of Electrical Engineering and Computer Science's course 6.163 continues to be the main effort of the Stroboscopic Light Lab. Some 25 students a term take the course which is one of the few at MIT that contains a series of experiments which serve to meet the requirements of the Institute.

Each year there are a few students who become sufficiently involved to do their thesis investigations in work that started from the course.

The laboratory supports the photographic gallery (hallway) and a laboratory display exhibit, for visitors.

Three books are in distribution, regarding the Strobe Lab work: Moments of Vision; Electronic Flash, Strobe (MIT Press, Inc.) and Sonar Images (Prentice-Hall) published in January 1986.

#### FACULTY

This year the following faculty were promoted: Nancy A. Lynch to full professor; Robert C. Berwick, Lance A. Glasser, Robert H. Halstead, Jr., and Silvio Micali to associate professor.

Professor Robert S. Kennedy was appointed Vinton Hayes Fellow in support of his work in developing new communication networks systems; Raphael C. Lee was named the first Karl R. Van Tassel Career Development Assistant Professor of Electrical Engineering in recognition of his electrical and biomedical engineering background and, in particular, its application for human benefit in the field of biomedical engineering; Bruce R. Musicus, another first holder of a new chair, was named Rockwell International Career Development Assistant Professor of Electrical Engineering for his outstanding contributions to both education and scholarship in the software and hardware design of special purpose computers for digital signal processing; and Robert H. Kingston was appointed Adjunct Professor of Electrical Engineering. Joining our faculty this year were Roger T. Howe, formerly an assistant professor in the Department of Electrical and Computer Engineering at Carnegie-Mellon University, now Assistant Professor of Electrical Engineering; and Don P. Clausing, most recently principal engineer at the Xerox Corporation, who was appointed Bernard M. Gordon Adjunct Professor of Engineering Innovation and Practice. The Department was also pleased to welcome the following visitors: Mark J. Balas, Visiting Associate Professor of Electrical Engineering, on sabbatical from Rensselaer Polytechnic Institute, who conducted research with Professor Jeffrey H. Lang on the control and estimation of electromechanical systems; and Jean-Loup Delcroix, Directeur Général of the Ecole Supérieure d'Electricité in France, on a one-month appointment as Visiting Professor of Electrical Engineering, who participated in an interdepartmental teaching effort and collaborated on the writing of a plasma text.

A number of faculty achievements during the year deserve special mention: Richard B. Adler, Distinguished Professor of Electrical Engineering and Computer Science and associate head of the Department, was presented the Education Medal from the Institute of Electrical and Electronics Engineers (IEEE) for leadership in engineering education through teaching and textbooks in semiconductor electronics and electromagnetics; Dimitri A. Antoniadis, Associate Professor of Electrical Engineering, was named director of the newly established Microsystems Technology Laboratories located in the Gordon Stanley Brown Building; four faculty in the Department were among 100 engineers and scientists in the nation named by the National Science Foundation to receive Presidential Young Investigator Awards: Assistant Professors Robert C. Berwick, James G. Fujimoto, Roger T. Howe, and John N. Tsitsiklis. These awards are intended to help universities attract and retain outstanding young Ph.D.s who might otherwise pursue nonteaching careers; three members of the faculty were elected to membership in the National Academy of Engineering (NAE): H. Kent Bowen, Professor of Electrical Engineering and Ceramic Engineering, for leadership and innovative developments in the field of advanced ceramics; Professor Joel Moses, head of the Department, for pioneering accomplishments in symbolic algebraic manipulations by computer and for outstanding leadership in engineering education; and Professor Kenneth P. Stevens for acclaimed advances in deciphering the mysteries of speech recognition and production and for leadership of a distinguished speech center; Professor James D. Bruce, currently director of Information Systems at the Institute, will fill the newly created post of Vice President for Information Systems, effective July 1, 1986; Mildred S. Dresselhaus, Professor of Electrical Engineering and Physics, was named Institute Professor, a high honor reserved for a member of the faculty who has demonstrated distinguished accomplishments in scholarly, educational service and leadership pursuits. Professor Dresselhaus received a second major honor by being selected as the 1986-87 recipient of the James R. Killian, Jr. Faculty Achievement Award. Both honors were bestowed by her colleagues on the faculty; Professor Dresselhaus, who was made an honorary member of the MIT Alumni Association in the spring, was also selected by Phi Beta Kappa as one of 13 Visiting Scholars for 1986-87. She will travel to universities and colleges that have Phi Beta Kappa chapters to meet undergraduates, lead classroom discussion, and give lectures; David J. Edell, Assistant Professor of Electrical and Bioengineering, was included in an Esquire Magazine listing of notable recent achievers which cited his development of an implantable silicon chip that detects nerve impulses; Professor Harold E. (Doc) Edgerton was inducted into the National Inventor Hall of Fame for his invention of ultra high-speed photography; Shaoul Ezekiel, Professor of Aeronautics and Astronautics and Electrical Engineering, will be director of a new center, still to be named, but based on the Center for Advanced Engineering Study, and devoted to continuing education and special education initiatives, effective July 1, 1986; Assistant Professor Lance A. Glasser was presented the Frederick Emmons Terman Award by the Electrical Engineering Division of the American Society for Engineering Education in recognition of his insight into design strategies for electronics, for his principal authorship of the recent text, The Design and Analysis of VLSI Circuits, now being used in universities, and for his successful teaching efforts within the academic and industrial worlds; the Department and the School of Engineering established two endowed scholarship funds for undergraduates and named them for Professor, Emeritus, Truman S. Gray and Associate Professor, Emeritus, Charles Kingsley, Jr. in honor of their 80th birthdays; Assistant Professors Roger T. Howe and William E. Weihl both received two-year IBM Faculty Development Awards for untenured faculty, to enhance their career development as researchers and educators; Jeffrey H. Lang, Associate Professor of Electrical Engineering, was this year's recipient of the Harold E. Edgerton Award which is given annually to a junior faculty member who has made

outstanding contributions to research, teaching, and the MIT community; three members of the Department were elected Fellows of the IEEE: Jae S. Lim, Associate Professor of Electrical Engineering, for contributions to speech and image enhancement and digital signal processing; Dr. Bruce D. Wedlock, director of the Lowell Institute School, for his contributions and leadership in electrical engineering education; and Alan S. Willsky, Professor of Electrical Engineering, for contributions to the theory of estimation and detection in stochastic systems and to their application; Roger G. Mark, Matsushita Associate Professor of Electrical Engineering in Medicine, has been made co-director of the Harvard-MIT Division of Health Sciences and Technology; Terry P. Orlando, Associate Professor of Electrical Engineering, was awarded the 1986 Graduate Student Council Department Award for excellence in teaching; Claude E. Shannon, Donner Professor of Science and Professor of Electrical Engineering and Mathematics, Emeritus, received one of the first three Kyoto Prizes for his work in "Basic Sciences." The Kyoto Prizes are designed to reward accomplishments in fields not covered by Nobel Prizes; Professor Louis D. Smullin received an honorary Doctor of Science degree from the Technion Institute in Israel; John A. Tucker, director of the VI-A Internship Program, was elected Honorary Alumnus and member of the MIT Alumni Association by a nationwide vote of MIT alumni chapters; Mr. Tucker also received a plaque from the Massachusetts Beta Chapter of Tau Beta Pi in appreciation of thirty years of dedicated service as senior chapter advisor; Jerome B. Wiesner, Institute Professor and former president of MIT, received the NAE's prestigious Arthur M. Bueche Award for his long-term contributions to public understanding of the risks of the nuclear age and to efforts to reduce those risks, and for personal leadership in the areas of high-performance communications systems, science policy in the federal government, and scientific and engineering education; a number of books appeared during the year that merit recognition. Those published by the MIT Press were: The Acquisition of Syntactic Knowledge, by Associate Professor Robert C. Berwick; Robot Vision, by Professor Berthold K. P. Horn; Advanced Research in VLSI, edited by Associate Professor Charles E. Leiserson; Abstraction and Specification in Program Development, by Professor Barbara H. Liskov and Associate Professor John V. Guttag; and Circuits, Signals, and Systems, by Professor William M. Siebert; John Wiley and Sons published Programming in Common Lisp, by Assistant Professor Rodney A. Brooks, and Electromagnetic Wave Theory, by Professor Jin A. Kong; Sonar Images, by Doc Edgerton, was published by Prentice-Hall; and Theory of Holors: A Generalization of Tensors, co-authored by Associate Professor, Emeritus, Parry Moon (with Domina Eberle Spencer), was published by Cambridge University Press.

Department faculty who were away during the year included Professor Jack B. Dennis, on leave for the academic year, who supervised the operation and development of Dataflow Technology Corporation; Associate Professor John V. Guttag, on sabbatical for the academic year, who spent part of his time at Digital Equipment Corporation working on specification of distributed systems and part of his time at the University of Paris South where he gave seminars; Professor Berthold K. P. Horn, on leave for the academic year, who worked on motion vision and photogrammetry at the University of Hawaii; Professor Erich P. Ippen, on sabbatical spring term, who spent time at Technische Universitaet in Munich working on a new area of infrared pulse technology and also generated course notes on optics and quantum electronics; Professor Richard C. Larson, on sabbatical for the academic year, who conducted research in a new area of multidisciplinary approaches to queueing systems; and Assistant Professor Christopher J. Terman, on leave spring term, who furthered his work in computer architecture.

Edward Fredkin and Michael Hammer, Adjunct Professors of Computer Science and Engineering, have resigned. Dr. Hammer plans to pursue his business interests full time; Christopher J. Terman, Assistant Professor of Computer Science and Engineering, has also resigned from the faculty.

Louis D. Smullin, Professor of Electrical Engineering and head of the Department from 1966 to 1974, retired from the faculty. He will continue to be involved in the Department as senior lecturer.

The Department was saddened by the death of Professor, Emeritus, Karl L. Wildes who will be remembered for his contributions to the development of cooperative education at MIT. Professor Wildes may be best remembered, however, in his role as co-author of A Century of Electrical Engineering and Computer Science at MIT, 1882-1982, a history which marked the Department's 100th anniversary; the Department also took note of the passing of Mary L. Guillemin who, in memory of her late husband, Ernst A. Guillemin, established a fund in honor of his work at MIT. The Guillemin Fund has, since 1974, provided annually a prize for the best undergraduate thesis in electrical engineering.

JOEL MOSES



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## Department of Materials Science and Engineering

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### INTRODUCTION

This is an exciting time for the field of Materials Science and Engineering. We are presented with immense intellectual challenges, great opportunities to contribute to national and international needs, and many professional opportunities for our graduates. Philip H. Abelson summed up some of the sense of purpose we feel in an editorial in the June 20 issue of *Science*, in which he wrote "A materials science and engineering revolution is underway that will be a key factor in determining the outcome of global economic competition."

The growing perceived importance of the field of materials science and engineering helped greatly in making the academic year 1985-1986 another excellent one for this Department in its educational and research roles, and in development of its endowed and other funding. We project our undergraduate enrollment to average over 45 per class next year, thus remaining at or near an all time high. At the graduate level, our total enrollment has reached 277 after a steady increase in recent years. Both the number and quality of our graduate applications continue to rise, but limitations of space, facilities, and faculty dictate that we not further increase this student body.

We were the grateful recipient this year of a \$2 million grant from IBM for strengthening our work in electronic materials and processing science. We share this grant with the new Polymer Program in Science and Technology. This grant, and our new Alcoa Assistant Professorship, will provide a sound financial springboard for the three new junior faculty whom we have hired, and who will start their teaching careers this coming fall.

It is also gratifying to be able to report the establishment in this Department of a new endowed professorship, the TDK Professorship in Materials Science and Engineering, formed with a grant of \$1 million from the TDK Corporation. The chair is awarded for a five-year period; its first recipient is Professor Bernhardt J. Wuensch.

We were deeply saddened to lose Professor Thomas B. King, who passed away last Thanksgiving. His humor, his wit, his kindness, and his love of M.I.T. and its students are characteristics that we will long remember. He taught for nearly 33 years and carried out an internationally respected research activity on thermodynamics and kinetics of high temperature systems, in the John Chipman tradition. He was Head of this Department for 10 years from 1962 to 1972. In addition to his extensive teaching and counseling duties over the years, he served in his final decade as Director of our important Co-op Program. We sorely miss his presence.

Professor Nicholas J. Grant, 70, retired this year after spending his entire career at Massachusetts Institute of Technology where he has educated over 200 graduate students and visiting scientists and inspired countless undergraduate students. He, his students and co-workers have contributed greatly to the field of metallurgy, especially in the areas of high temperature materials, chemical metallurgy, powder metallurgy and rapid solidification processing. Last year I reported that we held his retirement party a year early and that it was decided at that time to initiate an endowed "Nicholas J. Grant Graduate Fellowship." I am delighted to report that only one year later we have received over \$200,000 in donations, or two-thirds of the endowment required to support a graduate student studying in this Department. The rapid growth of this fund is a testimonial to the affection and regard Nick's students and colleagues hold for him. I also mentioned last year that we anticipate Professor Grant will remain active on our faculty as an emeritus professor for many years to come, and I can write with assurance that all signs point to that being the case.

The Department of Materials Science and Engineering continues to be an outstandingly strong research department. Figures for research dollar volume for the fiscal year ending in June 1986 are not yet available, but the total is expected to be higher than the previous year, when volume was approximately \$13.4 million per year, supervised for the most part by individual faculty or by groups of faculty. This research was administered through the Department (51%), the Materials Processing Center (28%), the Energy Laboratory (12%), the Center for Materials Science and Engineering (4%), and other laboratories and centers (5%).

Major research efforts continue in each of the different classes of materials: ceramics, metals, polymers, and electronic materials. One way of categorizing our research activities (without regard to materials classes) is:

Materials Science	{	Structure and Transformations	}	Materials Engineering
		Structure/Property Relations		
		Structure/Processing Relations		
		Property/Performance Relations		
		Process and Systems Modeling		

A great strength of the Department, and a feature that is unique among academic materials departments is that we have programs underway in all of the above five categories, and in all of the materials classes. Raising adequate research funds has not been a problem for the great majority of our faculty, and from a departmental standpoint, our strategy is to encourage research programs that (1) most strongly enhance our teaching programs, (2) contribute most effectively to national and societal needs, and (3) otherwise most effectively contribute to our long range objectives.

The continued strengthening of the Department and the broadening of its programs have been made possible in large measure by the continued support of industry and the continued interaction of the Department with industry. Twelve of our faculty now hold named chairs, of which five are endowed and seven are term. The five endowed chairholders and chairs are: H. Kent Bowen, Ford Professor of Engineering; Merton C. Flemings, Toyota Professor of Materials Processing; W. David Kingery, Kyocera Professor of Ceramics; R. Erik Spjut, John Chipman Assistant Professor of Chemical Process Metallurgy; and Bernhardt J. Wuensch, TDK Professor of Materials Science and Engineering. The seven term chairholders and chairs are: John F. Elliott, AISI Distinguished Professor; Ronald M. Latanision, Shell Distinguished Professor; Gretchen Kalonji, Norton Assistant Professor of Materials Processing; Gary E. Wnek, ARCO Associate Professor; Yet-Ming Chiang, DuPont Assistant Professor; David A. Rudman, Edgerton Assistant Professor; and Carl V. Thompson, Mitsui Assistant Professor.

Industrial and individual support of other aspects of the Department's academic and research programs have also been generous; these include undesignated funds, funds for scholarships and fellowships, and funds for endowment accounts including the Nicholas J. Grant Graduate Fellowship. Industrial research for the Department is handled largely through the Materials Processing Center. This Center, under the able direction of Professor Ronald M. Latanision, has continued to grow so that its total research budget during the last academic year was \$7 million, of which more than \$3 million was from industry.

In 1888 the word "metallurgy" crept into the title of this Department when the Department changed its name from that of "Mining Engineering" to "Mining and Metallurgy." We count that date as our beginning and so will be celebrating the 100th anniversary of our Department in 1988. Plans for the celebration are being developed by an internal committee under the chairmanship of Professor Morris Cohen, and by an alumni committee now being formed. Our celebration will be on the days between the M.I.T. Commencement on Friday, May 27 and Technology Day on Friday, June 3. We plan a technical program of substance and a social program of merit to mark this joyful occasion.

#### THE UNDERGRADUATE PROGRAM

The revision of our undergraduate laboratories is well underway. This revision, being carried out with a critically important \$1 million grant from the Balfour Foundation, is aimed at upgrading laboratory equipment and at revising the laboratory offerings to encompass the four materials classes: electronic materials, ceramics, metals and polymers. We hope to formally dedicate the "Balfour Laboratory" during the coming academic year.

We have begun now to focus special attention on our undergraduate academic core subjects. Materials Science and Engineering, as an arena of intellectual activity, is little more than a quarter of a century old. In universities, it grew largely from metallurgy departments. The Department of Materials Science and Engineering at M.I.T. was at the forefront of this development. Our faculty led in showing that the concepts and approaches which had proved so fruitful in metallurgy could be broadened to encompass other materials as well. Now, the opportunities and intellectual ferment in our field are attracting great attention of chemists, condensed matter physicists, electrical engineers and others. These individuals are bringing greater intellectual breadth to our field, broadening our horizons, and broadening also the academic material we wish to convey to our students. It is always challenging, and sometimes painful, to decide what material can be condensed, what can be made more generic, and what is no longer needed, but the time has come for us to re-address this important issue. To guide us in our task, we have established a new Undergraduate Core Curriculum Committee under the chairmanship of Professor David K. Roylance, to work with the Undergraduate Committee under chairmanship of Professor Donald R. Sadoway.

Professor Roylance's Committee will study our undergraduate core courses, and the relationships of the courses with each other. The Committee will make both near term and long term recommendations. The centrally important challenge for the Committee will be to further define the important principles of the evolving field of Materials Science and Engineering, outline how these principles should best be taught to undergraduates, and consider the practical examples that can illustrate application of these principles.

Our undergraduate enrollment next year is projected to be an average of over 45 students in each of the sophomore, junior and senior classes, once again at or near an all time high. The Co-op Program (Course IIIB) continues to draw a major fraction of our undergraduates. Approximately 70% of our juniors and seniors are now in the cooperative program. Professor Regis M.N. Pelloux, working with Mr. Joseph M. Dhosi, has assumed directorship of this program. With so many of our students now in that program, it has become necessary for us to improve our procedures in matching students, companies, and projects. Professor Pelloux and Mr. Dhosi are initiating steps to do this, and will be in contact with past and prospective employers in the early fall regarding proposed new procedures. This program is an important one for our students and for this Department. It has proven to be of great value to many companies in helping them come to know well exceptional young men and women who are, or soon will be, looking for permanent employment. More information concerning this program is available from Professor Regis M.N. Pelloux, Room 8-237, M.I.T., Cambridge, MA 02139.

#### THE GRADUATE PROGRAM

In September 1985 there were 277 graduate students enrolled in the Department, up from 252 the previous year. Both figures constitute new records. Of this number, 57 were newly admitted students; and an additional 10 were admitted in February 1986. As of the fall semester, of the total graduate students in the Department, 68% were supported by research assistantships, 6% by teaching assistantships, and 22% by fellowships. The remaining students relied on their own funds or on outside sources. Approximately 68% of the graduate students were from the United States. The students were divided among the Degree Programs in February, 1986, as follows:

<u>Degree Program</u>	<u>% of Students</u>
Ceramics	19
Electronic Materials	22
Metallurgy	20
Polymers	11
Materials Science	12
Materials Engineering	16

The DCGS (Departmental Committee on Graduate Students) under the new chairmanship of Professor Samuel M. Allen will be looking closely during the coming year at the graduate curriculum, including those core courses that cut across materials classes and are intended to be basic to all of our degree programs.

The new interdepartmental "Polymer Program in Science and Technology" (PPST) is now formally underway. Its first class has been admitted and will begin in the fall of 1986. In this interdepartmental degree program, students are admitted only through departments. Two of the six students in this new program are from our Department, and faculty from our Department have played key roles in helping initiate the program. Professor Robert E. Cohen of Chemical Engineering is the first Program Director. Important funding for the program has been obtained as part of the IBM support given us for Materials and Processing Science of Electronic Materials mentioned earlier.

#### FACULTY

Three new assistant professors were invited to join our faculty this year and will do so beginning in the fall semester. These individuals are Professors Michael J. Cima, Michael F. Rubner, and Andreas Mortensen. Professor Cima comes to us from Berkeley where he did his research in high temperature chemistry under Professor Brewer. He will work in ceramic processing and will hold the title of IBM Assistant Professor. Michael Rubner comes to us after experience at GTE and a doctorate at M.I.T., to strengthen our teaching and research in polymer/electronic materials. He will also be an IBM Assistant Professor. Professor Andreas Mortensen received his degree at M.I.T. and is currently Visiting Researcher at Nippon Steel in Japan. His professional area is composite materials and mechanical metallurgy, and he will be the Alcoa Assistant Professor.

Professor Harry L. Tuller and Professor Joel P. Clark were promoted to Full Professor and Professor Gretchen Kalonji was promoted to Associate Professor during the past year. Professor H. Kent Bowen was elected to the National Academy of Engineering, bringing to 13 the number of our faculty and faculty emeriti who are in the National Academy of Engineering, the National Academy of Science, or both.

Professor Nicholas J. Grant, as mentioned earlier, retired this year at the age of 70 but continues to be strongly active in the Department. Professor Robert L. Coble has also retired after 26 productive years on the faculty of this Department. He has been, and remains, an international leader in sintering and sintering theory. In the course of his basic work on sintering and sintering theory, he discovered a method for producing translucent and later transparent ceramics. This was a notable achievement which led to the well-known "Lucalox lamp" and to other important ceramic advances. We are fortunate that Professor Coble will remain with us as Professor Emeritus and will continue to be active in the Department.

Professor Samuel M. Allen received the Graduate Student Council Teaching Award for 1986. Professor Robert W. Balluffi was elected a Fellow of the Institute of Metals (Great Britain). He also received a Humboldt Stiftung, was elected a Fellow of the Japan Society for Promotion of Science Research, and elected Councilor of the Materials Research Society.

Professor Michael B. Bever completed publication of his major eight-volume work, Encyclopedia of Materials Science and Engineering, published by Pergamon Press and M.I.T. Press. Professor Coble was awarded the Frenkel Prize for contributions to theory of the International Institute of Science of Centering. Professor Morris Cohen delivered the Kimball Burgess Memorial Lecture to the ASM, Washington Chapter. Professor Elliott delivered the 20th Sir Julius Wernher Memorial Lecture to the Institution of Mining and Metallurgy in London. Professor Flemings delivered the Yukawa Memorial Lecture to the Japan Iron and Steel Institute and received the Luigi Losanna Gold Medal from the Italian Metallurgical Association. Professor Hobbs has been elected President of the Electron Microscopy Association of America. Professor Latanision received the David Ford McFarland Award for achievement in metallurgy from the Pennsylvania State University. Professor Rudman received a Fulbright Grant for a summer scientific research mission to France. Professor Szekely was the Nelson W. Taylor Memorial Lecturer, Pennsylvania State University. Professor Vander Sande received the Gillette Award.

#### STUDENTS

The Student Undergraduate Materials Society (SUMS) had an active and spirited year. After a hiatus of some years, the undergraduate student organization was re-organized two years ago under its new name by an Executive Committee consisting of undergraduate students Mary L. Manger, Louise M. Sedlacek, and Mark A. Wolf. The purpose of SUMS, as stated in its constitution, is to promote fellowship among students in the Department, to facilitate communication between faculty and students, and to keep students informed of, and involved in, Departmental policies and events. During the last year, SUMS conducted mid-term evaluations of undergraduate courses, arranged a series of lunchtime seminars, and held an Academic Forum to discuss undergraduate core and restricted elective subjects. A detailed and constructive report emanating from that Forum is serving as an important starting point for our discussions on undergraduate curriculum revision. On the social side, SUMS worked jointly with the Graduate Materials Council in initiating our Monday afternoon coffee breaks. They also held a skating party, several pizza parties, and a picnic barbecue to celebrate the end of the spring semester. New officers of SUMS, elected in February, are Maria L. Galiano, President; Lisa S. Gassaway, Vice President; Ryoichi R. Shiono, Treasurer; Sharon L. Fletcher, Secretary. Louise M. Sedlacek serves as Academic Committee Chair and Stephen W. Russell as Social Committee Chair.

Three members of our class of 1986 were awarded graduate fellowships by AT&T Bell Laboratories. The three are Sergio A. Ajuria and Sossina M. Haile, winners in the Bell Labs Cooperative Research Fellowship Program, and Mary L. Manger, who received one of the three fellowships nationwide in the AT&T Bell Labs Graduate Research Program for Women. Each fellowship, in addition to summer employment at Bell Laboratories, provides all tuition, fees, books and a monthly stipend for the student's entire graduate career. Mary L. Manger was also elected to Phi Beta Kappa honor society, a rare and prestigious honor for a student in the School of Engineering. Mary was also a finalist for the 1986 AMITA Award, presented to the senior woman student in recognition of outstanding academic and professional achievement. Melissa A. Krawiczki was co-winner of the Kathryn Langford Wolfe Award. Dodd H. Grande received the Athletic Department Gold Award for student leadership and service in the administration of M.I.T. athletics. Raymond J. Meilunas received the Best Thesis Award for the academic year. Louise M. Sedlacek was elected the first woman captain of the varsity sailing team in its 50-year history. She was also chosen as "Most Valued Player" for the season. Linda M. Sprys received the Straight T Award for outstanding performance in regional and national swimming competition during the 1985-86 school year. She finished first in the 200-yard butterfly at the New England Division III Championships.

The Graduate Materials Committee (GMC), now under the chairmanship of Simone C. Peterson, continues its strong leadership role. The Committee worked with SUMS to carry out subject evaluations and to put on the popular Monday afternoon student-faculty coffeetime. The GMC also continued the monthly Friday afternoon departmental social hour, and conducted a series of luncheon seminars. Newly-elected officers of the Graduate Materials Council are: David H. Matthiesen, Chairman; Simone C. Peterson, Vice-Chairman; Michael J. Warwick, Social Chairman; Steven C. Semken, DCGS and GSC Rep; Mark A. Buonanno, Member, GMC.

David R. Forrest was one of ten national winners of Honeywell's 1986 Futurist Awards Competition. Janine M. Nell won the Compton Prize, as President of the M.I.T. Graduate Student Council who revitalized its activities in housing and community affairs, and constructed a database to make the organization more effective.

Fellowship awards for one or more semesters were held during academic year 1985-1986 by 24 students. These were: Bell Labs, Marcus W. Shute; Eastman Kodak, Linda S. Mason; IBM, Michele M. Donovan, Mark S. Goorsky, Thao A. Nguyen; INCO, Thomas M. Harris; G.E. Foundation, Harold Kahn; Hertz Foundation, Alan S. Litsky; Hughes Aircraft, Joanna M. McKittrick, Ariana N. Sarabia; MPC Industrial Collegium Fellowships, Gary M. Carinci, Kathryn A. Dannemann, Julia C. Duncan, David C. Eng, Lloyd H. Hihara, Elizabeth J. Opila and Larry P. Sagert; NSF Fellowships, Manuel P. Oliveria, II and James S. Speck; ONR Fellowships, Terry J. Garino, Richard J. Higgins, and Stanislaus A. Zygmunt; U.S. Steel, Timothy V. Johnson; and Xerox, Kimberley Elcess.

Partial fellowships held by this Department's graduate students were: Aerospace Corporation, Karen G. Phelan; Beneficial Foundation, Patricia A. Morris; Horace Smith Fund, Ilya Gorodisher; Philips Laboratories, Peter F. Bordui; MPC/TRW Augmentation Fellow, Andreas Mortensen; Wyman-Gordon Foundation, Glenn R. Romanoski and Allison S. Warren.

#### RESEARCH

Professor Allen's research on effects of adsorption on interfacial migration continues to provide important new insights. In-situ observations using a heating stage in the transmission electron microscope are enabling observation of the "break away" regime of solute-drag behavior for antiphase boundaries. He is undertaking a new theoretical thrust on effects of interface stress on interface structure and behavior, and is computing complex carbide equilibria in secondary hardening steels, for applications in alloy design. Professor Averbach continues his work on development of new materials and concepts for high speed bearings in gas turbines. In Professor Balluffi's work on the atomistic structure of grain boundaries, he has observed hierarchical grain boundary dislocation structures in [001] tilt boundaries and calculated the coarse structures of grain boundary dislocations. Professor Bowen's multidisciplinary research on ceramic processing continues to be of worldwide international interest. Professor Chiang has made significant advances in his research on non-stoichiometric grain boundaries in multicomponent oxides and in establishing relationships between lattice stoichiometry, grain boundary non-stoichiometry, and properties of interest. He is also, with Dr. James Cornie, leading a broad new research effort into the processing of ceramic matrix composites.

Professor Clark's Materials Systems Laboratory has expanded its sponsorship base to 25 companies representing five countries. Professor Coble reports success in making and documenting the highest purity aluminum ceramic yet reported, with processing steps established. Professor Cohen's initiative with Dr. Olson and with other faculty on "innovations in high strength steel technology" is now well underway involving nine graduate students, three research associates, and seven off-campus research groups. He has made encouraging progress in combining the use of rapid solidification with lanthanum additions to improve resistance to hydrogen embrittlement in ultrahigh-strength steels. His continuing work on the mechanism and kinetics of martensitic transformations has been couched in the new phenomenology of dislocation theory, permitting more quantitative treatment of certain aspects of the transformations. Professor Eagar's research on resistance spot welding has been expanded to encompass both automotive and aerospace problems of practical importance. Studies have begun on development of ceramic to metal braze alloys.

Professor Elliott received support from the National Science Foundation to investigate the physical chemistry of an innovative bath smelting operation for the production of steel, in which the liquid oxysulfide phase in the iron-oxygen-sulfur system would serve as the smelting medium. Professor Flemings, working with Dr. Y. Shiohara and others, completed a major phase of his research on solidification of undercooled metals. They developed and tested a growth model that combines a new theory of Lipton, Kurz, Trivedi with classical coarsening theory. In his work with Dr. James Cornie, Dr. Andreas Mortensen and others, he studied solidification of metal alloys within infiltrated ceramic preforms, and illustrated the major effect these preforms, have on dendritic growth and microsegregation.

Professor Harry Gatos working with Dr. Lagowski discovered a new class of semi-insulating III-V compound semiconductors based on doping with titanium. This discovery should have a direct impact on microelectronic applications and should facilitate rapid progress in InP-high speed and microwave integrated circuits. Also with Dr. Lagowski, he discovered the butterfly defect responsible for a new intrinsic gettering process in aluminum. This process can be incorporated into a silicon device processing cycle improving yield and performance of integrated circuits. Professor Grant, in his work on rapid solidification achieved grain sizes of 0.2 microns in a multiphase alloy, which exhibited superplastic deformation at the highest recorded strain rates to date, and at relatively low homologous test temperatures.

He obtained the highest strength values yet reported for a ductile aluminum alloy, and he developed the first rapidly solidified high strength aluminum alloy which exhibits superior fracture toughness properties, made by liquid dynamic compaction. Professor Keith Johnson continued development of cluster molecular-orbital models for the electronic structures of amorphous semiconductors, amorphous alloys, and metal-semiconductor interfaces. He is continuing development of personal microcomputer software for calculating electronic structures of materials from first principle quantum mechanics.

Professor Kalonji with Professor Balluffi and with important help from the Sloan Fund and other sources developed a computational center for materials science simulation. She developed new techniques to calculate free energies of segregation to crystalline defects and to calculate local stresses associated with crystalline defects for atomistic simulations. She continued her experimental programs on rapid solidification of magnetic and structural ceramics. Professor Kingery's research focused on grain boundary chemistry of oxide, carbide and nitride ceramics, lattice and boundary defects in oxides, nitrides and carbides, and on techniques for and applications of holistic artifact appreciation and interpretation. Reviewers have described his new book Ceramic Masterpieces - Art, Structure, and Technology as an "epochal book that will be one of the standards for the study of ceramics", a "pioneering volume" containing "insights we've never had before", and "the first grand unified theory in the study of the major ceramic traditions of the world".

Professor Latanision's research continued to emphasize the chemical stability of advanced materials. Particularly gratifying has been the development and evaluation of new technologies for the characterization of the chemical, electrical and mechanical properties in situ of thin polymeric films on test chips. Professor Lechtman has made major progress in the final stage of a three-stage research program concerning the production and use of copper-arsenic alloys by prehistoric societies. In addition, a major program of research involving the nature of metallurgical technologies in prehistoric Ecuador was begun in association with the Museums of the Banco Central del Ecuador.

Professor Masubuchi continued his welding research with studies on laser forming of steel plates, on residual stresses in weldments, on development of remotely manipulated underwater welding systems, and on welding of newly developed high-strength steels. Professor McGarry continued his work on thin elastomer films in cross-linked glassy polymers. Professor Owen brought his work on the thermally activated motion of martensitic interfaces to a successful conclusion and made excellent progress in his work on nitrogen strengthening of austenitic stainless steels, identifying the complex strengthening mechanisms involved. Professor Pelloux's work on mechanical properties included studies on fatigue crack growth in superalloy single crystals, and a study of fatigue performance of rail steels. Professor Rose carried out the first in vivo experiments with a new bone cement at the Tufts University Veterinary Facility. Results were positive. He also developed, designed and constructed the first vacuum dielectrophoretic separator. Professor Roylance's research continues to emphasize the mechanical properties of polymers and polymer-matrix composites, and how these properties are related to processing and microstructure.

Professor Rudman probed the upper critical field anisotropy in thin film NbN by cross-sectional TEM and angular dependent high field studies, and found it originates in the fine grained microstructure of the films. Professor Russell initiated research on solidification of metal matrix composites. Professor Sadoway succeeded, for the first time, in taking Raman spectra in situ during electrolysis in a laboratory scale aluminum reduction cell operating at industrial conditions. Professor Spjut developed and calibrated a high speed pyrometry system and a low noise position sensing system in an electrodynamic thermogravimetric analyzer. Professor Szekely has made advances in the mathematical and physical modeling of three-dimensional flows as applied to materials processing operations including electromagnetic stirring, chemical vapor deposition, and the magnetic dampening of crystal growth.

Professor Thompson has shown that grain boundary atomic mobility in silicon is a function of the Fermi energy. He has produced 1 micron thick aluminum films with grain sizes up to 1 mm. across via a process that should be compatible with integrated circuit fabrication. Such large grained aluminum interconnects are highly resistant to electromigration induced damage. He carried out the first detailed study of grain size distribution and abnormal grain growth in thin films and developed an improved analytical and computational model for this microstructure evolution. He has proposed a new mechanism for heteroepitaxy in thin film systems characterized by island growth. Professor Tuller established the role of the oxidation states of transition metal impurities in YAG in controlling the electrical and optical properties. As a part of his research on fast ion conducting glasses, he developed a novel electrochemical technique for examining the nature and growth kinetics of reaction layers. In his work on Mn-Zn ferrites, he developed a detailed model of cation disorder on the 2 spinel cation sublattices that has been successfully applied to interpret experimental measurements.

Professor Vander Sande employed transmission and scanning transmission electron microscopy to provide a clear interpretation of the complex phase transformations that occur in Al-Li-X alloys with X equal to Ti, Zr, Hf. Unique microstructures were developed and interpreted. Theoretical and preliminary experimental work is underway in preparation for receipt next year of a new intermediate voltage field emission scanning transmission electron microscope. This instrument should allow obtaining compositional information from solids with a spatial resolution below 1.0 nanometers. Thus, it should be possible to analyze the composition of nearly everything that can be seen in the electron microscope, a goal of the electron microscopy community for the last two decades.

Professor Witt succeeded during the last year in growing 4-inch diameter dislocation free silicon single crystals. Professor Wnek rationalized how addition of protons to polyaniline leads to a material which exhibits electronic conductivity. The simple mechanism proposed is consistent with spectroscopic, magnetic and transport data. His program on the synthesis of non-linear optical polymers has begun. He discovered a novel route to substituted polyacetylenes and demonstrated, by an EPR spin probe study, what the mechanism of ionic conduction is in alkali metal salt/polyether complexes. Professor Wuensch continued his neutronscattering studies at elevated temperatures on the high temperature, fast ion conducting phases of several halides and chalcogenides which had before been prepared in single crystal form.

#### RESEARCH STAFF

The research staff of the Department of Materials Science and Engineering plays an important role in helping conduct almost all facets of the department's activities except formal classroom teaching, and even here they often contribute effectively on an ad hoc basis. During the last academic year the Department had 64 research staff members among its ranks, in the positions of Senior Research Associate, Principal Research Associate, Research Associate, Post Doctoral Associate, Sponsored Research Staff Member, and Visiting Scientist. An additional 28 research staff members, appointed through the Materials Processing Center, were associated with departmental faculty. The top two ranks on the research ladder are the positions of Senior Research Associate and Principal Research Associate. These titles are currently held by six individuals who are either appointed through this Department or through a separate laboratory or center, but whose work strongly focuses in this Department. Senior Research Associates are Drs. John S. Haggerty, Jacek Lagowski, and Gregory B. Olson. Principal Research Associates are James A. Cornie, Robert C. O'Handley, John F. Mandell and Paul D. Bristowe.

Dr. Haggerty has developed and supervises a major laser laboratory, specializing in ceramics processing. He has made significant progress in modeling the production of ceramic powders and of thin films by laser synthesis. The silicon and silicon carbide powders produced in his laboratory after consolidation have exhibited the highest strength yet reported -- two to five times stronger than is normally observed. He has made amorphous photovoltaic devices without air exposure, and has successfully made silicon nitride insulating films for the first time from laser heated gases. Dr. Lagowski, working with Professor Gatos, shares with him and other co-workers the discovery of a new class of semiinsulating III-V compound semiconductors based on doping with titanium, and shares also the discovery of a butterfly defect responsible for a new intrinsic gettering process in silicon. In addition, he discovered during the last year inversed thermal stability in gallium arsinide which offers new means for processing integrated circuits.

Dr. Olson's recent theoretical work on nonlinear elastic effects in martensitic nucleation has led to the discovery of a new phase transformation mechanism termed quasi-martensitic instability, the displacive analog of spinodal decomposition. His new university/industry/government program on high strength steel technology, initiated with Professor Cohen and other faculty members is now well underway, under the overall leadership of Dr. Olson. He is showing, in work with Professor Cohen, how the combination of lanthanum additions and rapid solidification may lead to a new class of steels resistant to hydrogen embrittlement. Dr. Olson was this year's Sauveur Memorial Lecturer of the Boston Chapter of the American Society for Metals.

Dr. James A. Cornie has developed a major program on the processing of composites, including primarily metal matrix and ceramic composites. He works jointly with a large number of faculty and students in guiding this major program of great technological interest. Dr. Robert C. O'Handley's magnetic materials research has continued to attract widespread interest for both its scientific quality and its technological relevance. New, high-energy product permanent magnets based on Fe-Nd-B were made in bulk form in collaboration with Prof. N.J. Grant. He produced the first strongly magnetic quasicrystal, and is pioneering in application of new spin-polarimetry techniques to surface studies of magnetic materials.

Dr. John F. Mandell's research is also largely in the area of composites, in polymer matrix and in ceramic-ceramic composites. His most important research advance during the last year was in identifying a mechanism which produced improved resistance to the growth of fatigue cracks in reinforced thermoplastics. Dr. Paul D. Bristowe's computer simulation studies of grain boundary structure and properties have been significantly enhanced by the creation of the Computational Center for Materials Science Simulation, with Professors Balluffi and Kalonji. His calculations continue to focus on determining the atomic structure of boundaries using variational and dynamic techniques, with particular emphasis on correlation with experimental data obtained by x-ray diffraction. New calculations based on density functional theory have also been initiated which will determine from first principles the atomic and electronic structure of boundaries in semiconductors as well as in metals.

MERTON C. FLEMINGS

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## Department of Mechanical Engineering

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### INTRODUCTION AND PERSPECTIVE

The mechanical engineering profession is broadly concerned with energy, motion and materials, and the design, production, and management of systems to meet the needs of society. The profession will have a central role in addressing the challenges of the 1980's and beyond relating to the supply and efficient utilization of energy, manufacturing and productivity, safe and efficient transportation, defense, enhancement of the environment, and health care and human rehabilitation. Mechanical engineering practice is changing rapidly due to the increasing capabilities of computation, information processing and measurement control technology, the continued development of the fundamental disciplines, the growing ability to synthesize new materials and processes, and an improved understanding of the life sciences and human factors. These rapid changes provide both significant challenges and opportunities to the profession and for the education of future engineers.

Student interest in mechanical engineering continues to be strong. The Department has the second largest undergraduate enrollment at MIT with a total of 457 undergraduates. The rapid rise in graduate enrollment during the last five years has been constrained by the Department with 439 full time graduate students enrolled this past year. The demand for students graduating with SB and SM degrees has remained strong throughout the last five years. The demand for PhD graduates interested in engineering education, particularly in the manufacturing and design areas, continues to be strong as universities respond to the national educational and research needs in these areas.

In the recent Gorman report published in the fall of 1985, the Department undergraduate program leading to an SB in Mechanical Engineering was ranked as number one in the nation and the Department graduate program has continued to be ranked as first in the nation.

This past year special emphasis has continued to be placed upon undergraduate curriculum development. Continued upgrading of equipment and instrumentation has occurred in the manufacturing, measurement and instrumentation, project and materials laboratories. Space has been renovated in the basement of building 3 for undergraduate instrumentation, project and design laboratory activities. A coordinated effort has been initiated to integrate real time data acquisition and analysis techniques into the undergraduate laboratories. Attention has also been focused upon strengthening computational capabilities for both undergraduate and graduate subjects under the auspices of Project Athena.

Faculty effort in identifying and developing research programs in the past year has been notable, particularly in light of the overall support/cost picture. Total sponsored research has grown in the last year by approximately five percent to reach a level of \$15.4 million. Approximately one-half of the research is administered directly by the Department and one-half by interdepartmental laboratories and centers with which faculty are affiliated. During the last year, small increases have occurred in research related to manufacturing and design, while support for biomedical engineering research has remained relatively constant as has support for energy and environmental areas. Research support from industry has continued to be significant representing approximately 25 percent of the total research administered through the Department.

During the year faculty in the fluid and thermal sciences area have strengthened research programs in computational fluid mechanics and turbulent reacting flows, the thermal-fluid processes controlling growth of electronic materials, energy efficiency in buildings and systems, and biofluid mechanics. Faculty in the mechanics and materials areas have developed research in high performance metals, fibers and polymeric materials, and continued major programs in geomaterials and biomaterials. Faculty in manufacturing, design and control have advanced the capabilities in flexible manufacturing and robotics and extended investigations into basic manufacturing processes. Faculty in the biomedical engineering area have continued to make significant progress in developments related to treatment of cancer patients using ultrasound, evaluation of artificial skin for burn victims and in understanding the biomechanics of joints and limbs as well as basic fluid processes related to diseases of the cardiovascular, pulmonary, and ocular systems.

Effort has continued in the development of the Martin Center for Engineering Design. This facility includes a prototype development laboratory, an interactive classroom, and special seminar rooms for design education and research. This past year Control Data Corporation has provided a CYBER 180/830 Computer System for the Center. At the same time, Project Athena is placing the first eight of 24 Digital Equipment Corporation workstations into the Interactive Classroom. Motorola has provided eight sets of microprocessor equipment for the prototype laboratory. These facilities will provide a unique opportunity for design education which incorporates computer-aided engineering techniques from concept generation through prototype development.



## PROGRAMS OF INSTRUCTION

### Objectives

The Department instructional programs strive to educate mechanical engineers for leadership roles in professional practice and engineering education, and to provide a broad flexible background for entering related fields such as medicine, law, management, and public policy. Programs emphasize a basic foundation in the engineering sciences combined with a strong design orientation and extensive laboratory experience which couples theory and analysis with the physical world. At both the undergraduate and graduate levels, involvement of students with faculty in research at the forefront of engineering practice--through special projects, the Undergraduate Research Opportunities Program (UROP) and theses--is a hallmark of the Department.

### UNDERGRADUATE PROGRAMS

#### Degree Program and Enrollment

The Department undergraduate program leads to the SB in Mechanical Engineering (Course II), which is accredited by the Accreditation Board for Engineering and Technology (ABET) or the SB without specification (Course II-A), which is non-accredited. Course II-B, the Engineering Internship Program, leads to the SB and SM in Mechanical Engineering with industrial experience as an integral part of the program.

The Department enrollment continued at levels comparable to the past few years. The new sophomore class of 159 included 57 women, 36 percent of the class, and 12 black students. Approximately 10 percent of the class are minorities.

Course II-A provides an alternative to the regular mechanical engineering program and is intended for those students who wish to design a special program coupling such areas as biomedical engineering, management, and energy policy with mechanical engineering. About 20 students were enrolled in II-A. The Department has been heavily involved in the School of Engineering Internship Program since its inception in 1977-78. This past year, 58 students from the Department are members of the Program out of a total of 117: 12 graduate students, 19 seniors and 27 juniors. In 1985-86 the Department awarded 141 SB degrees (123 in Mechanical Engineering, 13 without specification.)

#### Undergraduate Curriculum

The Department Academic Policy Committee has reviewed the content and cohesiveness of the undergraduate curriculum and has broadly defined the evolutionary development of the undergraduate curriculum over the next five years in three areas - (1) development of an integrated laboratory sequence starting with an introduction to instrumentation and measurement and leading to computer-aided data acquisition and analysis, (2) an increased coupling of manufacturing and design, and (3) a strengthening of the basic disciplinary subjects with improved computational techniques.

In a continuing curriculum development effort this past year, Professors William C. Unkel and C. Forbes Dewey, Jr. have introduced the use of computer-aided data acquisition equipment into two of the Department core undergraduate laboratories.

#### Undergraduate Student Organizations

The Student Chapter of the American Society of Mechanical Engineers under the leadership of its officers: Miriam Maxiam, President; Gregory Hammel, Vice President; Jesper Otterbeck, Treasurer; and Karim Salame, Secretary, continued to make strong contributions to Department and professional activities with a membership of 140 students. Professor Anthony T. Patera served as the Faculty Advisor.

Black ME is an organization of black students which provides a supportive environment for minorities in the Department. Membership in Black ME has continued strong with nearly 40 students. This past year the organization provided academic support in subject reviews, sponsored corporate presentations and had professional engineers make presentations for its membership. The organization was ably lead by Elihu McMahon, President; Andrew Gray, Vice President; Reginald Tucker, Secretary; and David Sangster, Treasurer. Professor Stephen H. Crandall served as the Faculty Advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continued its strong tradition of fostering student-faculty relations and serving the Department through its course and instructor evaluation program. Activities during the year included chapter meetings, classroom evaluations at mid-term and end-of-term, and a spring banquet to honor newly elected members. The organization was lead by: Jose A. Rivero, President; Thomas Kurfess, Vice President; Sandjay Govindjee, Secretary; and Heather Irving, Treasurer with Professor Warren P. Seering acting as Chapter Advisor.

Professor Ming-Kai Tse was Faculty Advisor for the Student Chapter of the Society of Manufacturing Engineers. The chapter officers were: Karim Salame, President; Jack Leifer, Vice President; Barb Hove, Secretary and Karina Fu, Treasurer. The SME sponsored two major seminars, one in automation and one in manufacturing and co-sponsored a meeting of Boston area SME chapters.

#### Undergraduate Student Awards

Many undergraduates in the Department were recognized for academic and athletic excellence, engineering creativity, and community service.

Jose A. Rivero and Sandjay Govindjee received the newly established John Glendening Prize for outstanding dedication and service in the Department of Mechanical Engineering.

Several students were recipients of the Departmental De Florez Award for innovation and creativity: James D. Worden, freshman, won first prize for his Solectria II-Solar-Powered Vehicle. Wade Takao Shimoda and Megan J. Smith tied for second prize--Shimoda for his Snowboard Binding and Smith for her Bicycle Lock.

Ramzi Y. Richani and Denise M. Bednarczyk won the Departmental AMP award for outstanding performance in project work in the mechanical engineering area.

Stanley B. Kyi, Stephen Swann, Michael W. Howard, Jason W. Dunham, Steven Beringhouse, and Timothy W. Hyland won the Departmental Robert L. Hallock Tensile Test Award for excellent machining and heat treating of a tensile test specimen in mechanical engineering.

Katherine F. Moore, Jene M. Spears, Kathryn Y. Kim, Howard M. Loree II, Bruce M. Schena, Christian S. Marx and Karen J. Annis won the Departmental Wunsch Foundation Silent Hoist and Crane Company award for outstanding design and fabrication in the mechanical engineering area.

Stuart B. Brown and Irina Rakin received the William L. Stewart, Jr. Award for their contributions to extracurricular life at MIT.

Yu-Ming Wang won the award for the best Mechanical Engineering Thesis relating to energy conversion, the Reinhold Rudenberg Memorial Fund. His thesis was titled, "System Identification and Control of a Direct-Drive Robot".

Julie Chen, senior, won the Malcolm G. Kispert Award for the female senior scholar-athlete of the year.

#### GRADUATE PROGRAMS

##### Organization

The graduate program is directed by Professors Ain A. Sonin, graduate policy and registration officer, Carl R. Peterson, graduate admissions officer.

##### Degrees

The Department offers the SM degree in Mechanical Engineering, the undesignated SM degree, the degree of Mechanical Engineer, and the doctorate in Mechanical Engineering. The undesignated SM degree allows students to design special interdisciplinary programs with thesis research performed in the Department, while the Mechanical Engineer program is intended as an alternative to the doctoral program for students who wish to emphasize applications and/or design, including economic and social aspects.

##### Enrollment and Degrees Granted

Graduate enrollment in the fall of 1985 was 439 full-time students. In the fall of 1985 there were 39 women, four black, four Hispanic, and five Asian-American students in the graduate program. In September 1985, 297 new students were admitted from 497 applicants and 144 students registered.

In 1985-86 the Department awarded 131 SM degrees (of which 6 were combined SB/SM degrees), seven Mechanical Engineer degrees and 20 doctoral degrees.

In 1985-86, 93 percent of all graduate students received support from the Department, MIT funds, fellowships, the government or industry. Sixty-six percent of the graduate students were supported by the Department through research and teaching assistantships.

## Graduate Curriculum Development

During the past year five new graduate subjects were introduced by Department faculty to strengthen our programs in materials, manufacturing and control:

2.303J/3.26J	Micro Mechanisms of Fracture
2.302J/3.25J	Physics of Inelastic Deformation of Solids
2.35	Role of Microstructure in Mechanical Behavior
2.845	Nondestructive Evaluation and Quality Engineering
2.152	Advanced Control System Design

Three new textbooks were developed by faculty during the past year including Robot Analysis and Control by Haruhiko Asada and Jean-Jacques Slotine, Tribophysics by Nam P. Suh, and Advanced Fluid Mechanics Problems by Ascher H. Shapiro and Ain A. Sonin.

## Graduate Student Awards

The Goodwin Medal, recognizing "conspicuously effective teaching" by students was awarded to Eric G. Vaaler, during the annual Institute-wide Awards Convocation.

Thomas R. Kurfess received the Departmental Service Award for outstanding dedication and service, the John Glendening Prize.

## RESEARCH

### Support Level and Distribution

The total volume of sponsored research for 1985-86 is estimated at \$15.4 million, representing a growth of five percent from the research volume last year. Approximately one-half of the total research is administered through the Department and one-half through interdepartmental laboratories and centers. The Department sources of research support are derived from a wide spectrum of government agencies and industries. The trend of the last few years of a significant portion of research supported by industry has continued and approximately 25 percent of the research administered through the Department has been from industry. Several laboratory groups derive 50 percent or more of their support from industry including the Resource Extraction Laboratory, the Innovation Center, the Laboratory for Mining and Systems Development, the Laboratory for Manufacturing and Productivity, and the Computer-Aided Design Laboratory.

Several companies and foundations continue to provide grants of unrestricted funds to the Department and funds to support the career development of young faculty. These discretionary funds have been used as seed funds to initiate new research areas, to enhance the development of young faculty careers and to acquire equipment for education and research. Several young faculty were supported this year by the Alcoa Faculty Fellowship, the IBM Grant based on excellence in materials and manufacturing research, the DuPont Engineering Grant and the Rockwell International Assistant Professor Fellowship. These grants have provided significant assistance in initiating research activities by young faculty and the commitment they represent from industry to education is most encouraging.

Research in the Department varies from very basic, fundamental research to the conception, design, and prototype evaluation of innovative systems to serve the needs of society. Approximately half of the faculty are explicitly involved in basic research and almost every research project in the Department has a component of fundamental research. In research applications the faction of faculty involved in the four major application areas are: manufacturing, materials and mechanics, 35 percent; energy and environment, 45 percent; biomedical engineering, 22 percent; and systems, including transportation, 18 percent.

### Research Accomplishments

#### Manufacturing, Materials and Mechanics

The major Department activities in manufacturing and processing are associated with the Laboratory for Manufacturing and Productivity (LMP). This interdepartmental laboratory is a focus for research which systematically explores the complex interactions among the many facets of design and production and involves faculty in major program areas of manufacturing automation and robotics, metals processing, polymer processing, flexible materials, and tribology. Significant progress has been made in the robotics area through the research of Professors Neville Hogan, Seering, Slotine and Kamal Youcef-Toumi. Development of direct drive motors for robots by Professor Youcef-Toumi, techniques for obstacle avoidance through impedance matching of robot characteristics to the environment by Professor Hogan, improved structural elements for robot arms by Professor Seering, and robot control algorithms by Professor Slotine have all been encouraging. Research in polymer processing has been performed through the MIT-Industrial Polymer Processing Program by Professors Suh in materials development, Timothy G. Gutowski in composite materials, and Tse in nondestructive evaluation. Professor David E. Hardt has continued research to improve welding processes and metal forming processes through direct application of automatic control

techniques. Professor Steven Kim has started a research program in axiomatic design for manufacturing using artificial intelligence techniques while Dr. George Chryssolouris has initiated a program in intelligent manufacturing. The industrial consortium under the direction of Professor Ernest Rabinowicz and Dr. Nannaji Saka has been expanded with the addition of several new companies to pursue basic research in tribology related to magnetic recording devices, fuel efficient engines and the mechanisms of friction and wear. The research program in flexible materials developed by Professor Stanley Backer has developed an improved understanding of the behavior of fibrous rope materials.

In the Mechanics and Materials area, research conducted by Professors Ali S. Argon, Frank A. McClintock, David M. Parks and Lallit Anand is seeking to develop a better quantitative understanding of the wide variety of processes involved in the mechanical behavior of materials including inelastic deformation, fracture, and thermo-mechanical coupling effects. Applications of the fundamental analytical techniques and basic experimental studies have been conducted for hot-forming of metals, inelastic response of glassy polymers, development of physically-based models of creep damage, mixed-mode elastic plastic crack propagation and interfacial behavior in metal matrix composites.

A number of faculty are directing their research to development of advanced analytical and experimental techniques in mechanics and dynamics. Professor James H. Williams, Jr. has continued in the development of nondestructive techniques to characterize composite materials. Professor Klaus-Jurgen Bathe has led the development of finite element models for fluid-structural interactions. Professor Crandall has developed analytical formulations and experimental techniques to identify the dynamic behavior of rotor-shaft dynamic systems as well as multi-dimensional plate behavior. Additional research in the mechanics area has been performed by Professor Triantaphyllos R. Akylas who has made significant progress in developing analyses for the dynamic behavior of fluid waves and their interactions with the environment.

#### Energy and Environment

During the year, substantial progress was made in research programs related to the combustion and lubrication in internal combustion engines, resource extraction, heat and mass transfer, and energy conservation. Research in the REMERGENCE Laboratory, a laboratory facility developed under the joint auspices of the Mechanical and Civil Departments, has been further developed by Professor Michael P. Cleary in evaluating rock fracture related to oil and gas extraction and by Professor Peterson in research directed to improving mining systems.

In the heat and mass transfer area, Professors Patera and Bora B. Mikic have performed analyses, corroborated by experimental data which indicate substantial augmentation of heat transfer rates may be achieved by modulating unsteady flow in channels.

Research in the Sloan Automotive Laboratory has been undertaken with the support of industrial consortiums to evaluate the uses of ceramic materials in engines and to develop improved understanding of combustion. This effort involves Professors John B. Heywood, Wai K. Cheng and Ahmed P. Ghoniem and is complemented by basic research in lubrication conducted by Dr. David P. Hoult. Fundamental studies related to the characterization of combustion have been extended to consideration of turbulent combustion by Professor Tau-Yi Toong.

Several new research programs have been initiated in the Cryogenics Laboratory under the direction of Professor Joseph L. Smith, Jr. and Dr. Yukikazu Iwasa. Major progress has been made in the development of a prototype superconducting generator and in the development of cooling systems for high performance magnets which have application to medical imaging.

In the Chemical Dynamics Research Laboratory, Professors James C. Keck and Unkel have continued the development of a basic understanding of chemical interactions and energy exchange processes associated with electrical discharge phenomena with application to spark ignition laminar burning and homogeneous explosions of combustible gas mixture and arc welding.

Experimental studies to characterize two-phase gas-liquid flows associated with power systems have been conducted by Professors Peter Griffith with particular application to emergency cooling of nuclear reactors.

Research in the area of turbomachinery has been continued by Professor Maher A. El-Masri with emphasis on exploration of liquid cooling for gas turbines. In addition, Professor David Gordon Wilson has continued research in developing design algorithms for turbomachinery.

Research directed to energy conservation associated with improved heat transfer performance of building insulation materials has shown considerable progress under the direction of Dr. Leon R. Glicksman in a program conducted jointly with the Department of Architecture. In addition, Professor Thomas P. Bligh has recently completed a major project to acquire operating data determining the utilization of solar energy in houses.

A number of fundamental research studies have been conducted this year. Fundamental research in the quantum mechanic foundations of thermodynamics has been continued by Professors Gian Paolo Beretta and Elias P. Gyftopoulos. Professor James A. Fay has developed basic methods of characterizing the dispersion of gases in the atmosphere with application to acid rain. Research to determine transport of heat and mass transfer across vapor-liquid surfaces in low gravity environments has been initiated by Professor Sonin. Professor Ronald F. Probstein has conducted research in the control of ground water at hazardous waste sites.

#### Biomedical Engineering

In biomedical engineering research, encouraging progress has been made in areas related to human mobility and sensory aids, treatment of tumors via hyperthermia, development of artificial skin and development of an understanding of the fluid mechanics related to the cardiovascular, pulmonary and ocular systems.

In the Eric P. and Evelyn E. Newman Laboratory for Biomechanics and Human Rehabilitation. Professor Robert Mann directed research that culminated in a telemetered hip endoprosthesis providing the first measurements of pressure in the hip joint ever made in a human. The information is crucial to the understanding of how the mechanical and biological characteristics of cartilage, bone and synovial fluid work together to achieve high-load capacity, low friction and long wear. Studies conducted in the laboratory by Professor Woodie Flowers have continued the development of a microprocessor-based biofeedback and gait analysis system for training above-knee amputees in the use of prostheses while effort to develop aids for the handicapped has continued by Dr. Michael Rosen.

Research results obtained by Professor Ioannis Yannas in collaboration with Dr. John F. Burke of Massachusetts General Hospital to evaluate a Stage 2 biocompatible artificial skin for severely burned patients have been encouraging.

In the Laboratory for Medical Ultrasonics, Professor Padmakar Lele and his colleagues have continued in the patient evaluation of research in which tumors are treated through controlled hyperthermia using focused ultrasound.

Biomedical research in the fluid mechanics laboratory has shown significant progress in the recent work of Professor Roger B. Kamm in developing a basic understanding of the hydrodynamics of ocular solutions in the eye related to diseases such as glaucoma. Professors Shapiro and Kamm are collaborating on research involving theoretical and analytical studies of the flow in collapsible tubes related to arterial flows. Also, research by Professor Dewey on identifying genesis of arteriosclerosis has continued in the experimental quantification of the effects of shear stress on arterial flows.

#### Systems Research

In systems and transportation, research is concentrated in the Man Machine Systems Laboratory, the Computer-Aided Design (CAD) Laboratory, the Vehicle Dynamics Laboratory, the Machine Dynamics Laboratory, and the Innovation Center.

Professor Thomas B. Sheridan and Dr. Dana R. Yoerger of the Man Machine Systems Laboratory have made significant progress in the development of undersea remote manipulation with the establishment of an experimental test capability to evaluate and modify an undersea manipulator in research coordinated with the Woods Hole Oceanographic Institute.

Professor David C. Gossard and his colleagues in the (CAD) laboratory have developed automatic scaling techniques for mechanical assemblies which allow scaling to be performed on the basis of design and prescribed constraints in objective functions. This research is complemented by effort to develop, using expert systems technology, designer-machine interfaces which enhance the iterative design functions.

The activity in the machine dynamics and control area has continued to grow with efforts of Professor Steven Dubowsky, Richard H. Lyon, and Seering. Professors Dubowsky and Seering have continued efforts to develop analytical and experimental techniques for evaluation of high speed machine performance, while Professor Lyon has further developed techniques for analyzing vibration signatures as a diagnostic tool in rotating machine performance with a detailed application study of diesel engine characteristics.

In transportation technology, Professors David N. Wormley and J. Karl Hedrick have initiated research relating to automation in the rail industry and to development of dynamic models for evaluation of vehicle energy consumption. Research in the control and dynamic performance of automotive vehicles and in truck/pavement interactions was also conducted by Professor Hedrick.

The Innovation Center, under the leadership of Dr. David Jansson, has continued both basic research into the processes of innovation and development applied to industrial and consumer products.

## FACULTY AND STAFF

### Size and Composition

On July 1, 1985 there were 59 active faculty: 31 professors, 19 associate professors (11 with tenure), and nine assistant professors. Eight faculty are minority group members: a black professor and seven Asians. The teaching, research, and technical staff fluctuates at around 70, more than half of whom are part time people whose principal base is either in another department or outside MIT: many of these part time faculty serve without stipend. Among the staff are three Asians, one Hispanic, and three women. Of the seven administrative staff, five are women and of the 35 support staff one is a black woman and one is an Asian. The Department has 11 hourly staff, including two black men.

### Notable Accomplishments and Awards

Professor Akylas was named the Henry L. Doherty Professor in Ocean Utilization in 1985 and continues his appointment for one more year. Professor Akylas has also received a Presidential Young Investigator Award.

Professor Anand continued his two year appointment as the Esther and Harold E. Edgerton Assistant Professor.

Assistant Professors Gutowski and Ghoniem were promoted to the rank of Associate Professor. Professor Ghoniem was also named the Esther and Harold E. Edgerton Associate Professor for a two year term.

Professor Bathe received the Graduate Student Council Award for his excellent teaching of and interaction with the graduate students. Professor Bathe also received the 1985 Gustus L. Larson Award from Pi Tau Sigma and ASME for outstanding achievements in Mechanical Engineering.

Professor Suh continued in his duties as the Assistant Director of the National Science Foundation. The Society of Manufacturing Engineers honored Professor Suh with the F.W. Taylor Research award in recognition of his basic contributions in manufacturing research and Dr. Chryssolouris, associate director of the Laboratory for Manufacturing and Productivity, with the annual Young Manufacturing Engineer Award.

Professor Hardt succeeded Professor Suh as director of the Laboratory for Manufacturing and Productivity.

Professor Ernest G. Cravalho has been named Chief of Biomedical Engineering at the Massachusetts General Hospital while also being named to the new Edward Hood Taplin Professorship which links Harvard University, MIT and the Mass. General in pioneering research in medical engineering.

Professor Heywood was named the 1986 ASME Freeman Scholar.

Professor Lyon has been named Fellow of the American Association for the Advancement of Science.

Professor Mann has been designated a Fellow of the American Society of Mechanical Engineers for his work on communication and mobility aids for the blind and on cybernetic prostheses for the amputee, as well as his pioneering involvement of students in design undertakings. Professor Robert Mann has also been named Director of Bioengineering Programs at the Whitaker College of Health Sciences, Technology and Management beginning July 1 of 1986.

Dr. Carlo Deluca, senior lecturer in the Department, has been elected a Fellow of the Institute of Electrical and Electronics Engineers.

Professor Rabinowicz received the Mayo D. Hersey Award for his work in tribology from the American Society of Mechanical Engineers.

Professor Backer was named an Honorary Member of The Fiber Society for life in recognition of his outstanding contributions to the field of fiber science.

Colleagues from around the world of Professor Crandall celebrated his 65th birthday with a festschrift to honor him for his many contributions to the field of random vibrations.

A major effort during the year has been the establishment of two Fellowships to provide financial support to graduate students. One of the fellowships was established to honor Professor Warren Rohsenow, who retired in 1985. Professor Rohsenow served as the Graduate Registration Officer to 25 of his 39 years at MIT. The Ascher H. Shapiro Fellowship was established by contributions from former students, by contributions from former students, friends and colleagues of Institute Professor Shapiro. Professor Shapiro is retiring after nearly 50 years at MIT.

### New Faculty and Staff

Five new faculty have been appointed to the Department during the last year.

Dr. Shahryar Motakef joined the Thermal and Fluid Sciences Division in July as an Assistant Professor. Professor Motakef will teach heat transfer and provide leadership in experimental engineering subjects and will continue to develop a research activity related to the fluid and thermal characteristics of electronic materials.

Professor Rohan Abeyaratne was appointed as an Associate Professor of Mechanical Engineering in January. He previously was on the faculty at Michigan State University and will strengthen the Department's activities in the Mechanics and Materials area.

In the Manufacturing Area, Dr. Kim has been appointed as Assistant Professor of Mechanical Engineering. He will teach in the area of manufacturing and design and is establishing a research program in the area of axiomatic design and manufacturing integration.

Dr. William K. Durfee was appointed as an Assistant Professor in the Systems and Design Division where he will develop teaching activities in the direct digital control systems area. His research is concerned with the applications of control in biomechanics.

Dr. Youcef-Toumi was appointed as an Assistant Professor in January to the Systems and Design Division. He will add strength to the control teaching activities and his research will focus on trajectory control of direct-drive robot arms in the flexible manufacturing area.

### Resignations/Retirements

Institute Professor Shapiro retired after 41 years at MIT. Professor Shapiro's association with MIT began with his SB and ScD degrees, followed by an instructor appointment. He joined the faculty as an assistant professor in 1944 and became an associate professor in 1947 and professor in 1952. He was appointed Ford Professor of Engineering in 1962 and became an Institute Professor in 1975. In 1964-65 he served as Chairman of the MIT faculty, resigning that post to become Head of the Department of Mechanical Engineering. He remained Department Head until 1974.

Professor Unkel resigned to devote a major part of his efforts to the development of UnkelScope Software.

Professor Bligh resigned to accept a position at Cambridge University in England.

### Deaths

Professor Emeritus Hesselschwerdt, died January 17, 1986 at age 75. Professor Hesselschwerdt had been a member of the MIT faculty since 1942 teaching mechanical engineering, architecture and food technology until his retirement in 1975.

Professor Emeritus of Mechanical Engineering, Dean of Students and Head of General Science and General Education, John Thomas Rule, II passed away May 24, 1986. Professor Rule joined the faculty in 1936 and retired in 1966.

DAVID N. WORMLEY

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## Department of Nuclear Engineering

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As the academic year 1985-86 draws to a close, the faculty and staff of the Nuclear Engineering Department can reflect on the events of the past year and feel a sense of accomplishment. Significant achievements include the inaugural Rose lecture, the progress of curriculum review, and national recognition of Department faculty. More detailed information regarding these events will be presented later in this report.

Within the past year, the computer facilities of the Department have been increased to meet the needs of our students. A new facility in Building 24 has been equipped and is now in full operation. Also, the computer room in Building NW12 has been completely refurbished and equipment upgraded. Between these locations, nuclear engineering students now have a variety of equipment available for their use.

The Department's conference room was completely remodeled and now provides a more pleasant atmosphere for meetings and social gatherings. The corridors and headquarters area of Building 24 have been freshly painted and present a welcoming, cheerful appearance for faculty, staff, and students.

### ACADEMIC PROGRAM

During the fall term 1985, 153 students were enrolled in the nuclear engineering graduate program. International students represented approximately 35 percent of the total enrollment. Our undergraduate program, although small, registered approximately 25 students during the past academic year. Next September, the undergraduate registration is expected to increase significantly with the addition of 10 freshmen who have elected the nuclear field.

Applications for graduate admission have shown a slight increase over the past year. Fifty-three domestic applications have been received. At present, we expect to welcome 28 students in September. A majority of the incoming class who have requested financial aid will be supported by departmental funds.

Since our last report, 63 degrees have been awarded to 60 graduates. The breakdown is as follows: 30 doctorates, 3 nuclear engineers, and 30 master of science degrees. In addition, 9 bachelor of science degrees were granted.

Since its inception, the Engineering Internship Program has been a very valuable learning experience for our students. At the present time three participants are interning at EG&G Idaho, Stone & Webster, and Brookhaven National Laboratory.

During the past year, faculty and graduate students have held considerable discussion regarding review of the departmental curriculum and the associated structure of the doctoral qualifying examination. The objectives of the curriculum review were to focus the qualifying examination on more fundamental materials, to adjust the offering of courses to be consistent with the examination schedule and to revise course content to encompass evolving subject materials. As a result of these discussions, the faculty voted to issue a revised list of graduate courses and qualifying examination requirements as well as institute a major requirement (36 credits) in addition to the existing minor requirement (24 credits) for PhD/ScD candidates. This new policy has been published and will be implemented as of September 1986.

As a result of the above-mentioned curriculum review, several changes have been implemented. One of these was the introduction of a new course 22.341 Nuclear Energy Economics and Policy Analysis which was taught by Professors Michael Driscoll and Richard Lester during the fall term. During the spring term Professor Jeffrey Freidberg and Dr. Daniel Cohn presented a revised version of 22.062/602 in which they devoted a large effort to the explanation of how existing fusion experiments are built and operated from a technological point of view. In the coming year a new subject, 22.113 Nuclear and Atomic Collision Phenomena will be offered by Professor Sidney Yip. This course will emphasize the use of quantum mechanics in describing various nuclear and atomic collision phenomena.

### RESEARCH

During the fiscal year ending June 30, 1985, Departmental faculty supervised a research volume of more than \$3 million. This figure includes research funded through the Department, the Department of Materials Science & Engineering, the MIT Energy Laboratory, the Whitaker College of Health Sciences, Technology and Management, the Nuclear Reactor Laboratory, the Plasma Fusion Center, and the Research Laboratory of Electronics.



### Continuing Research Projects

A major effort of continuing research has been the Nuclear Power Plant Innovation Project. The four principal elements of this study are 1) the light water reactor (LWR) innovation project, 2) the modular high temperature gas reactor (MHTGR) project, 3) the liquid metal reactor (LMR) studies, and 4) institutional and policy analysis.

The important areas of activity for the LWR innovation project are new plant performance requirements, conceptual design innovation and independent technological advances. Faculty involved include Professors Eric Beckjord, Michael Golay, David Lanning, John Meyer, Elias Gyftopoulos, and Neil Todreas. The MHTGR project is concentrating its efforts on safety, investment, and licensing issues. Current projects involve issues of source-term/core-design interaction, applicability of safety goals, incentives for fuel quality improvement, and determination of design goals. Professors Driscoll, Lanning, Lester, Lawrence Lidsky, and Norman Rasmussen, along with nine graduate students, are involved in this research. Under the direction of Professors Driscoll and Andrei Schor, research on decay energy removal by natural convection to air liquid metal cooled fast reactor units is continuing. Professor Driscoll recently completed a licensing strategy assessment for advanced LMRs, and has initiated another project to evaluate the economic projects of core design alternatives for the integral fast reactor (IFR) and the waste disposal issues associated with the pyrometallurgical process used to reprocess its fuel. Professor Lester leads the investigation involving the institutional and policy analysis portion of the overall project.

Under the supervision of Professors Kent Hansen, Gyftopoulos, Golay, Beckjord, Rasmussen and Lester, research continues in the collection and analysis of performance records of LWRs in the U.S., West Germany, France, Japan, Sweden, and Switzerland. This work is in collaboration with Professor Dietmar Winje and the staff of the Technical University of Berlin.

Study in the area of radioactive waste management and disposal continues under Professor Lester's supervision. His research in this area is concerned with the assessment of the risks of geologic disposal of high-level radioactive waste and the development of regulatory policies for waste disposal.

Professor Lester is also continuing his research into the sources of international variations in industrial performance in nuclear power plant construction and operation. This work focuses on the influences of industrial structure and safety regulatory practices on performance. He has also initiated a study of the effects of learning by doing on power plant capital costs and operating reliability.

Professor Hansen is the coordinator of a multimillion dollar, multiyear, Department of Energy (DOE) program involving 12 faculty principal investigators from five engineering school departments. Research areas include: thermal plasmas, fracture mechanics, automated welding, and engineering analysis and design.

Research in the area of advanced simulation tools is being continued by Professor Schor and his students. The software already developed under ATHENA sponsorship will be introduced on a pilot-basis as an educational aid in September 1986.

In the area of nuclear reactor instrumentation and control, Professors Allan Henry, Lanning, Meyer and Schor, are individually and jointly involved in various aspects of this type of research. Staff from the Charles Stark Draper Laboratory are also assisting the principal investigators. The MIT Research Reactor (MITR-II) has been used for demonstration and also for research in fault-tolerant digital control systems. Also during the past year, Professor Henry and his colleagues have successfully applied the unknown-but-bounded control modeling technology to a single model of a nuclear power plant.

An analysis of radioactive source term for postulated accidents in a modular HTGR has recently been completed by Professors Rasmussen and Lanning for the Idaho National Engineering Laboratory. They have also developed a mini-computer program for level 1 PRA of a modular HTGR. As part of the Electric Power Research Institute's program on severe LWR accidents, Professor Mujid Kazimi is continuing to study the impact of uncertainties of core-concrete interaction on the source term in severe LWR accidents.

In the reactor physics area, Professor Henry and his students have continued their investigation of the various aspects of reactor modeling. Among their accomplishments are the following: application of the QUANDRY nodal method to the analysis of cycle-1 of the ZION-2 reactor; the systematic derivation of other nodal models; the use of discontinuity factors to make standard finite difference equations reproduce transport effects; and, development of a successful method to determine BWR fuel-pin-powers from nodal solutions. In collaboration with Professor Driscoll, a supernodal method has been developed and tested for determining power distributions in PWRs during depletion and load follow transients.

Under the supervision of Professors Hansen, Henry, Golay, and Meyer, research continues on the development of the "parity" analog simulation approach to problems in neutron kinetics, fluid flow, and neutron diffusion. The concept has been successfully applied to single phase fluid flow, as well as the boiling of water.

Research in the area of nuclear materials and radiation effects is under way to develop predictive models for the evolution of the chemistry in cracks and crevices in high temperature aqueous systems. Under the supervision of Professor Ronald Ballinger, an investigation is under way to study the effect of environmental and microstructural factors on the cracking susceptibility of Ni-Cr-Fe alloys used in nuclear power systems. Professor Otto Harling is exploring ways of developing improved nuclear structural alloys for the critical fusion reactor first-wall application.

Efforts in the area of thermal hydraulics and fluid flow have been continuing by Professors Kazimi, Schor, Golay, Meyer, and Todreas. Their investigations cover such topics as: single phase channel behavior under decay heat conditions; flow distribution and heat convection mechanisms in bare and wire-wrapped bundles; analysis of heat transfer and hydraulics of two-phase flow; and advanced computational methods for single and two-phase flows.

Departmental activities in the fusion area, both theoretical and experimental, have been continuing under the supervision of Professors Freidberg, Ian Hutchinson, Kazimi, Kim Molvig, and Thomas Dupree. An investigation is being conducted by Professor Freidberg to determine the MHD equilibrium and stability limits of magnetic confinement systems. Another fusion project involves an analytic study of tokamak reactor design which is aimed at optimizing reactor geometry. Study in the area of nonlinear and turbulent fluctuations in plasma is continuing under the direction of Professor Dupree. Professor Kazimi's interest in the area of fusion safety focuses on the assessment of post accident thermal behavior of various blanket designs and the chemical kinetics of Li fires.

Professor Hutchinson and his students, in pursuit of additional diagnostic information on auxiliary heated tokamak plasmas, have developed a technique for determining the electron distribution function from measurements of non-thermal cyclotron radiation. His activities in the areas of MHD equilibrium and stability are currently focusing on problems relating to shaping and control of elongated plasmas in the proposed Alcator C-Mod upgrade of the MIT Plasma Fusion Center's Tokamak. Meanwhile, in a separate project the response of electric probes in strong magnetic fields with plasma flows is being studied from both theoretical and experimental viewpoints.

The field of radiation science and technology includes the areas of applied radiation physics and radiological science. Research in the applied radiation physics area is being conducted by Professors Sow-Hsin Chen and Yip. Small angle neutron scattering studies of structure and interaction of micelles, microemulsions and proteins is a major effort of Professor Chen. Professor Yip and his students are actively engaged in atomistic simulation studies of problems in materials science and statistical physics.

Professors Gordon Brownell and Alan Nelson are the principal faculty working in the area of radiological science. Professor Brownell and his research group have designed and built a positron tomograph, PCR-I, which is currently undergoing physical and biological testing. He is also continuing study on the production of epithermal neutrons and the distribution of boron compounds. A study of automated systems has led to interest in an accelerator using low energy deuterons for isotope production. Professor Nelson's major effort centers around biological imaging, medical imaging, and cancer research. In the biological imaging area, he has designed and built a transmission electron microscope with 3-D image capability and medium resolution using computer image reconstruction. A scanning electron microscope with 3-D image capability has also been designed and built. He has also integrated light microscopy and electron microscopy computer automation and image analysis for biological research. His activities in medical imaging research include such developments as an artificial intelligence system to search a head image to identify carotid arteries using combined phase and amplitude magnetic resonance images, and a system to delineate, measure, and display brain lesions in 3-D for research in autism, stroke, brain injury, and Alzheimer's disease. In the area of cancer research, he has shown that one pathway in tumor metastasis involves vasculature which penetrates to the tumor necrotic region to permit cancer cell entry into the bloodstream. Through his research he has demonstrated that local thrombosis of tumor vasculature either delays or prevents metastasis.

#### New Research Projects

A new project being carried out under the aegis of the innovation project is a DOE-sponsored study of the applications of modern programming languages, PROLOG in particular, to controlling the unavoidable complexity associated with nuclear reactor Technical Specifications and surveillance requirements. This work, supervised by Professors Lidsky and Lanning, has resulted in a demonstration computerized Technical Specifications monitor. Discussions are under way with a local utility for further development and for testing at an operating nuclear plant.

Professors Harling and Driscoll have obtained funding for a major new project directed towards dose reduction in LWRs. Their approach is based on research and testing with in-pile loops which simulate the PWR and BWR environments. Currently these loops are being designed and their installation into the MITR-II is expected to begin in about a year.

A project to evaluate various evacuation planning strategies for advanced liquid metal reactors has been initiated by Professors Rasmussen and Nathan Siu. This work will be funded by Rockwell International Corporation and is part of the MIT program on advanced reactor design concepts. A study to determine the impact of PRA on plant aging has recently been undertaken by Professor Rasmussen. He has also proposed a plan to develop a method for requalifying a plant for a defined period beyond its licensed life based upon plant failure rate data.

Professor Schor has initiated two new projects both dealing with advanced power system component modeling. The objective of the first project is the production of a much improved design tool for larger power plant condensers, while the other project focuses on the multiphase flow phenomena in high power heat pipes.

#### STUDENT ACTIVITIES

The MIT Student Chapter of the American Nuclear Society (ANS), which is the official liaison between the student body and the Nuclear Engineering Department administration and faculty, has been actively involved in many professional, academic, and social activities throughout the past year. Such activities have included lectures to science classes at local schools, a weekly departmental seminar series, participation/input in curriculum review and Visiting Committee meetings, distribution of course evaluation forms, organization of student/faculty dinner meetings, departmental steak fries, intramural sports, and a holiday party. During the year, the ANS has also arranged for student escorts for visiting prospective graduate students.

In November 1985, former Secretary of Energy James R. Schlesinger was the invited speaker at the inaugural lecture of the David J. Rose Lectureship in Nuclear Technology. This lectureship, co-sponsored by the Nuclear Engineering Department and Alpha Nu Sigma, the national honor society for nuclear science and engineering, was established in 1984 to honor Professor Rose on the occasion of his retirement, and in recognition of his work in fusion technology, energy, nuclear waste disposal, and most recently with ethical problems arising from advances in science and technology.

#### Honors and Awards

ANS Scholarship Awards were presented to four of our students at the ANS annual meeting which was held in Reno, Nevada earlier this month. They are Peter Donis, an undergraduate, and graduate students Kevin Wenzel, Anthony D'Amico, and Kin Cheung. These prestigious awards are presented by the ANS to students of nuclear science and engineering in recognition of their outstanding efforts and academic achievements in pursuit of a college education.

Last April the Department announced its annual undergraduate awards at the monthly student/faculty dinner meeting. Peter Donis received The Irving Kaplan Award for the Outstanding Junior in Nuclear Engineering. Recipient of the Roy Axford Award for the Outstanding Senior in Nuclear Engineering was Jerry Martin.

Also at this meeting the Department awarded its graduate fellowships for the academic year 1986-87. The Manson Benedict Fellowship, in honor of our first department head, was presented to Kevin Wenzel. Charles Carney will hold the Theos J. Thompson Memorial Fellowship for the coming year.

For the year ending, fellowship holders have been Pekka Hakkarainen, the Manson Benedict Fellowship, and Chuan-Fu Wu, the Thompson Fellowship. Abdel Barakat, a first-year student, received the Sherman Knapp Scholarship during 1985-86.

As in past years, several of our graduate students have been honored with national fellowships. Department of Energy Magnetic Fusion Energy Fellowships were awarded to James Crotinger, Scott Haney, John Massidda, Craig Petty, and Justin Schwartz. Margarita Crocker, Anthony D'Amico, Tue Nguyen, Scott Simonson, and Kathy Yuracko were selected for DOE Nuclear Engineering Fellowships. The National Science Foundation (NSF) supported Madeline Woodruff, Michael Izenson, and Kin Cheung, a first-year graduate.

Graduates receiving support from the National Institutes of Health included Cheryl Denault, David Kennedy, Tien Nguyen, Bruce Parnas, and Suzanne Shedd. These students are all pursuing degrees in the area of radiological science.

Two of our fellowship recipients successfully completed their doctoral research in June. They are Jon Anderson, holder the the Schlumberger Fellowship in Radiation Physics, and Cynthia Nitta, who held the IBM Fellowship.

The Exxon Corporation sponsored Eric Sheu's doctoral work during the academic year 1985-86. The Department granted Ken Meyers a fellowship which was partially funded by the Institute of Nuclear Power Operations.

Mark Boehle, a Naval Academy graduate, was appointed by the Institute as a Rockwell International Graduate Fellow. Financial assistance from the Institute's Graduate and Professional Opportunities Program was provided to Rene Sanchez and Robert Scott. Vesna Dimitrijevic was funded from the McAfee Award. The Department's two MIT-endowed tuition scholarships provided partial support for approximately six graduate students.

Finally, we are pleased to report that during the past academic year approximately 50 percent of our graduate student body was appointed to the graduate student staff, receiving financial aid in the form of full- and part-time research and teaching assistantships.

#### FACULTY

During the past year the combined total of full-time faculty in the three professorial ranks was 25. The following information briefly summarizes the activities and accomplishments of our members during this period.

A special two-week summer course entitled, "Nuclear Power Reactor Safety," was presented once again during 1985. Under the direction of Professors Rasmussen and Todreas, this offering attracted members of the U.S. nuclear industry as well as those of the international community. Professor Henry prepared and offered a new program during the summer of 1985. His session entitled, "Modern Nodal Methods for Analyzing Light-Water Reactors," was also a very popular presentation.

During the past year the work of the Nuclear Power Plant Innovation Project has continued to attract attention in the U.S. and overseas. Professor Lester was invited to contribute to various workshops and seminars concerned with U.S. power reactor research and development goals, such as the NSF Workshop on Innovative Electric Power Systems - June 1986 (Washington). Professor Lidsky has been asked to testify before several congressional subcommittees regarding the virtues of the MHTGR and its potential role in the U.S. nuclear power future.

Professor Todreas acted as Co-Chairman of the 2nd International Topical Meeting on Nuclear Power Plant Thermal Hydraulics and Operations which was held in Tokyo, Japan, April 15 - 17, 1986. He also served as General Chairman of the Third International Topical Meeting on Reactor Thermal Hydraulics, which took place in Newport, Rhode Island last October. At the same meeting, Professor Golay was a speaker. In addition to the Newport meeting, Professor Golay has presented papers at international conferences in Tokyo and Seoul within the past year.

Last August, Professor Schor attended the National Heat Transfer Conference in Denver, Colorado, where he presented three papers. During the same month, he conducted research and delivered a number of lectures at the Oarai Engineering Center, Japan.

Professor Kazimi spent part of the summer of 1985 at the European Joint Research Center in Ispra, Italy. While there, he worked on their fusion technology and safety program.

Professor Yip was an invited lecturer at the Enrico Fermi Summer School of Physics, Varenna, Italy, last July-August. In April, he was an invited speaker at an international meeting on computer simulation and the glass transition at Oxford University. He presented lectures on simulation studies in materials science during a three-week travel in the People's Republic of China under a grant from the Marion and Jasper Whiting Foundation.

During the last year, Professor Brownell has been affiliated with the Symposium on Neutron Capture Therapy, held at Brookhaven, and the Symposium on Medical Imaging, at Irvine, California. He has also participated in international conferences that were held in London, Finland, and Tokyo.

Faculty members who have handled administrative responsibilities are as follows: Graduate admissions were reviewed by Professor Lanning, and Professor Yip continued as financial aid officer. Our thanks to both professors who will complete their term of duty as of June 30. They will be replaced by Professor Freidberg, who will serve as Admissions Officer and chairman of the Department's newly-organized admission's committee, and Professor Kazimi, who will be in charge of financial aid.

Thanks to the efforts of Professor Driscoll, graduate recruiting continued to be successful. Professor Henry represented the Department on the Committee on Graduate School Policy (CGSP). Professor Meyer, who chaired the Committee on Undergraduate Students, also served as the faculty advisor for both the honorary Alpha Nu Sigma Society and the ANS Student Chapter. Professor Ballinger was in charge of the UROP program as well as the Engineering Internship Program. Our Department's IAP activities were directed by Professor Schor. The Department's Safety Committee and its Computer Committee were chaired by Professor Todreas.

Nuclear Engineering faculty members have actively participated in both Institute and national professional activities throughout the year. Professor Rasmussen continues to serve as Chairman on the MIT Committee on Reactor Safeguard. He is also a member of the Institute Council on Environmental Health and Safety, the Plasma Fusion Center Visiting Committee, and the Plasma Fusion Center Committee on Affirmative Action.

Professor Rasmussen continues to serve on the National Science Board and also is a member of its Task Committee on Undergraduate Science and Engineering. He serves on the Princeton Plasma Fusion Center Visiting Committee, as well as the University of California, Berkeley, Nuclear Engineering Department Visiting Committee. He was recently appointed to the Brookhaven National Laboratory Department of Nuclear Energy Visiting Committee. In addition to serving as chairman of the National Research Council Committee on Hydrogen Combustion, he continues on the Scientific Advisory Board for the Cleanup of TMI-2.

Professor Gyftopoulos continues as Faculty Chairman of the MIT Sustaining Fellows Program. As of June 30 he completes his term as Chairman of the Committee on Discipline. He is also a member of the Committee on Energy Conservation Research of the National Academy of Sciences and the National Academy of Engineering.

Besides serving as departmental CGSP representative, Professor Henry holds membership on the Ad Hoc Committee on MIT's Military Involvement and on the Advisory Committee on Shareholder Responsibility. Professor Todreas serves on two Institute committees: the Committee on the Center for Materials Science and Engineering and the Committee on the Research Laboratory of Electronics. He is also chairman of the EG&G TMI-2 Accident Analysis Industry Review Group.

Other faculty holding Institute appointments include Professors Driscoll, Lester, Molvig, Kenneth Russell, and Lidsky. Professor Driscoll continues on a special faculty committee entitled, "Committee on the Writing Requirement." Professor Lester is a member of the Committee on International Institutional Commitments and Professor Molvig holds an appointment on the Faculty Club Advisory Board. Professor Russell is Chairman of the Student Activities Development Board. Professor Lidsky was recently appointed to the Engineering School's Commission on Undergraduate Engineering Education.

The interdepartmental Nuclear Reactor Laboratory is under the direction of Professor Harling. In addition to Professors Rasmussen and Harling, Professors Ballinger, Kazimi, and Lanning are also members of the MIT Committee on Reactor Safeguard.

Professor Lanning continues to serve on the Safety Audit Committee at Northern States Power Co., the Nuclear Safety Review and Audit Committee at Boston Edison, and the Source Term Review Group for Stone and Webster Engineering Corporation. Professor Hansen has been appointed to the Energy Research Advisory Board Panel on Civilian Nuclear Power, and to the Scientific Advisory Committee at the Idaho National Engineering Laboratory. Professor Golay was selected for the AIF Committee to Assess the Chernobyl Accident.

For the past year Professor Kazimi has been serving on a DOE panel charged with assessment of safety and economic aspects of fusion energy. He also continues as the fusion technology chairman of the advisory panel of DOE's Magnetic Fellowship Program. Professor Freidberg has been appointed to the Sherwood Theory Executive Committee which is responsible for the annual national meeting on magnetic fusion theory. Professor Lidsky continues to be involved in the various national reassessments of the Controlled Fusion Program and is a member of a recently convened OTA Review Panel considering national options in this area.

Faculty holding American Nuclear Society appointments include Professors Driscoll and Henry. Professor Driscoll serves on the Executive Committee of the Fuel Cycle and Waste Management Division and Professor Henry is a member of the Program Committee of the Mathematics and Computation Division.

Three faculty are represented on editorial review boards. They are Professor Todreas on the thermal design section of the Journal of Nuclear Engineering and Design; Professor Henry for Nuclear Science and Engineering; and Professor Freidberg on Physics of Fluids.

### Honors and Awards

Several of our faculty were bestowed with honors since our last report. Professor Rasmussen was named a 1985 recipient of the Enrico Fermi Award given by the U.S. Department of Energy. Professor Henry was inducted into the National Academy of Engineering. The Outstanding Teacher Award for the academic year 1985-86 was presented to Professor Freidberg by the MIT Student Chapter of the ANS.

### Appointment

Nathan Siu joined the faculty as Assistant Professor of Nuclear Engineering. His primary expertise is in the area of probabilistic risk and reliability analysis.

### Promotions

Michael Golay and Mujid Kazimi were promoted to the rank of full professor during the academic year.

### Sabbatical Leave

During the fall semester, Professor Freidberg was on sabbatical leave. He used this time to convert his 22.615 MHD Theory I classnotes into a textbook form which will soon be published by Plenum.

Norman Rasmussen enjoyed a sabbatical leave during the spring semester.

### Resignation

Eric Beckjord who has been a Visiting Professor of Nuclear Engineering for the past two years will leave the Department at the end of the summer.

I-Wei Chen, Assistant Professor of Nuclear Engineering, has accepted a position at the University of Michigan.

### Death

With great sadness we report the passing of Professor David Rose last October. Internationally known and respected, he enriched the lives of all those who came in contact with him. He will be missed by his colleagues and friends.

### SUMMATION

This report for the period ending June 30, 1986, highlights the overall activities of the Department for the academic year 1985-86. The Department's Activities Report, prepared for the NED Visiting Committee, provides a more extensive summary of our teaching and research programs, as well as providing the statistical information which pertains to the Department and its students.

NEIL E. TODREAS

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## Department of Ocean Engineering

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### PROGRAMS OF INSTRUCTION

#### Undergraduate Program

The Department of Ocean Engineering continued to implement its undergraduate-education plan, which has two key elements:

- 1) Maintain an excellent undergraduate program (but at minimum cost while enrollment stays low): Two subjects are offered strictly for undergraduates in both of which the emphasis is on the design of marine systems. We continue to offer these subjects and even invest in their improvement despite their low enrollment; they are the keystone of the Department's undergraduate degree programs. The Department's other undergraduate-level subjects, focusing on engineering fundamentals relating to the marine environment, continue to draw enrollments in the range of 30 to 50, largely because many entering graduate students do not have adequate academic background in the area and have to take these subjects.
- 2) Involve the faculty in undergraduate activities outside of the Ocean Engineering Department:
  - Assistant Professor Dale G. Karr has been appointed to be co-in-charge of one of the sophomore-level core subjects in the Department of Mechanical Engineering.
  - Professor Jerome H. Milgram (in collaboration with Associate Professor William C. Unkel of the Mechanical Engineering Department) brought near to completion a Project Athena initiative to place standardized laboratory/Athena interface computers in undergraduate laboratories in throughout the School of Engineering and in other MIT schools as well.
  - One-third of the Ocean Engineering faculty members who were in residence at MIT this year served as freshman advisors.
  - Assistant Professor Amiram Moshaiov will be a junior faculty resident next year in an undergraduate dormitory at MIT.
  - Plans have been developed to offer a unique freshman seminar next year giving MIT students an opportunity to become involved in computer-aided engineering in their first year.

The new freshman seminar will be built on the existing subject 13.00 Computer-Aided Hydrostatics and Hull Surface Definition. This subject was the focus of one of the early successes of Project Athena. Professor Justin E. Kerwin developed it to give students the opportunity to work interactively with a computer to gain insight and experience in the design of ship hull forms. Enrollment in this subject has been low, since it is taken only by sophomores in Course XIII. So, to make this experience available to more students (and possibly to attract more undergraduates to Course XIII), Professor Kerwin will divide the subject into two modules next year, the first one of which will be offered as a stand-alone freshman seminar during the first half of the fall term. This seminar may well be the first subject ever to allow MIT freshmen to get directly involved in computer-aided design. The unusual format of the seminar, extending only through the first half of the term, will reduce end-of-term pressure on the students enrolled, and it may even attract additional students.

#### Graduate Programs

The Program in Naval Construction and Engineering (Course XIII-A) is offered as a two- or three-year course largely to meet the needs of the US Navy in preparing naval officers to manage and supervise the design of complex naval ship systems. Thirty-one new students registered for the Course in June, a large increase over recent years. Since most of these students received their prior degrees five to ten years ago and in a variety of disciplines, the Department this year organized a new summer program for entering students to provide a broad review of fluid and solid mechanics, some fundamental naval architecture, and an introduction to the MIT computing environment. These topics have been integrated into a single 20-unit summer-term subject, and, for the first time in recent history, students in Course XIII-A are receiving a substantial part of their first-summer instruction from regular faculty members in the Ocean Engineering Department.

Until the mid-1970s, most graduates of Course XIII-A received the degree Naval Engineer, as well as a master's degree. As part of the reorientation of the Department in the 1970s more toward ocean engineering and less toward naval architecture, this degree was abolished, leaving the degree Ocean Engineer as the only degree available in the Department at this level. This year, the Department decided that the differences between Course XIII and Course XIII-A warranted having distinct degrees. It recommended and the MIT faculty and the Corporation have now approved the reinstatement of the degree Naval Engineer for graduates of the three-year program in Course XIII-B.

The faculty of Course XIII-A and Course XIII-B (Ocean Systems Management) collaborated in teaching a special subject in the spring term in which students worked as a project team, examining current problems of the US shipbuilding industry. Their study covered needs for new technology and the possible adaptation of recently developed technology from other industries and other nations to the US shipbuilding industry. But an even larger part of the study was devoted to organization and management and to the external relationships of the industry, including industry/Navy negotiations and disputes, government regulation, financing, and labor relationships. The subject was organized by Professor Clark Graham, Head of Course XIII-A, and Associate Professor Henry S. Marcus, Head of Course XIII-B (Ocean Systems Management). Professor J. D. Nyhart and Associate Professor Judith T. Kildow also participated in the planning and implementation of the study.

#### PROJECT ATHENA

The Ocean Engineering Department has placed a high priority on making Project Athena a successful experiment. Professor Kerwin's earlier contribution and Professor Milgram's nearly completed project have already been noted. This year, Assistant Professor Dick K. Yue brought on line a set of tutorials for use in the teaching of fundamental hydrodynamics. They have already proven highly successful, largely because they emphasize the role of the student in the learning process: They require the student to anticipate what is being demonstrated and to provide cues to the programs. Thus they force the student to think. Some elements of Professor Yue's approach have already been integrated into a much larger project elsewhere within MIT, and, following the publication of a paper on the tutorials this spring, he has received inquiries from professors at many other US institutions.

Other projects currently underway range from the teaching of design to the development of consensual data bases and strategies for the constructive resolution of conflicts, the latter being directed by Professor J. D. Nyhart.

#### MARINE DEVELOPMENT FUND ESTABLISHED

A permanent fund was established for the promotion of education and research in the marine field. It is the Department's intention generally to draw on just the income from this fund to support curriculum development, faculty development, fellowships and scholarships, and new research initiatives, but a flexible approach has been taken in order to respond to the interests of donors. Initial gifts for this fund totaled \$820,000.

#### FACULTY

Professor Martin A. Abkowitz was on sabbatical leave for the academic year. During the fall term, he held the Naval Sea Systems Command Research Professorship at the US Naval Academy. During the fall term he lectured in the People's Republic of China.

Professor A. Douglas Carmichael served as Chairman of the New England Section of the Society of Naval Architects and Marine Engineers.

Professor Chrysostomos Chrysostomidis was appointed to the Naval Sea Systems Command Research Professorship. He was on sabbatical leave during the spring term, working in Athens, Greece, on his research on computer-aided engineering and the dynamics of deepwater offshore structures.

Professor Ira Dyer became President of the Acoustical Society of America, and he was selected as Scientist of the Year by the Office of Naval Research.

Professor Emeritus J. Harvey Evans has been appointed as a Senior Lecturer and is teaching part of the new entry program for students in Course XIII-A.

Assistant Professor Dale G. Karr was named Doherty Professor of Ocean Utilization for 1986-87.



Associate Professor Peter N. Mikhalevsky resigned from MIT to take a research position in the Washington, DC, area.

Dr. Amiram Moshaiov joined the faculty as Assistant Professor of Ocean Engineering. Professor Moshaiov has been appointed to be a junior faculty resident in one of the MIT dormitories for undergraduates.

Dr. Nicholas M. Patrikalakis joined the faculty as Assistant Professor of Ocean Engineering.

Dr. Bjornar Pettersen of the Norwegian Technical University was a Visiting Associate Professor for the year.

Associate Professor Harilaos N. Psaraftis was on sabbatical leave for the academic year, teaching and doing research at the National Technical University in Athens, Greece.

Associate Professor Michael S. Triantafyllou was awarded academic tenure. In the spring term, he started a one-year sabbatical leave for research and teaching at the National Technical University in Athens, Greece.

Professor J. Kim Vandiver served as Associate Chairman of the MIT Faculty (first year of a two-year term). He continues to serve as Head of the Experimental Study Group in the School of Science.

Commander W. David Whiddon, Associate Professor of Naval Construction and Engineering, resigned from the faculty to take another assignment in the US Navy.

Assistant Professor Dick K. Yue was appointed chairman of the Ocean Engineering undergraduate program committee.

#### NAVAL SEA SYSTEMS COMMAND PROFESSORSHIP

In 1983, the Naval Sea Systems Command established and funded a five-year professorship in the Ocean Engineering Department to help support the Department's teaching and research programs. A year ago, Professor Chrysostomidis was appointed to this professorship for a two-year term. With this support, and in collaboration with Professor Patrikalakis and Mr. Michael S. Drooker, a staff engineer, he has been working to identify the fundamental issues for research in the area of design, especially design of marine systems. The team has now focused on problems of solid modeling, that is, the definition of the geometry and topology of three-dimensional objects. Existing methodologies, e.g., the use of "wire frames" and surface modeling, are inadequate for the computer-aided design of complex systems such as naval ships and offshore platforms. One particularly important aspect is the establishment of "adjacency conditions," statements that a computer program can use to determine without ambiguity the relationship between nearby objects in a complex system. Tolerance control is another aspect that is crucial in the fabrication of ships and platforms.

Professor Chrysostomidis and his colleagues have established a constructive working relationship with design engineers at the Naval Sea Systems Command and with research engineers at the related USN laboratories. MIT made an important contribution to this collaboration in the construction of the new Ocean Engineering Design Laboratory.

#### FACILITIES

One new facility was built and completed during the year, and several existing facilities were renovated and/or modified.

A new Ocean Engineering Design Laboratory was built on the fourth floor of Building 5. The old drawing room, which had been unused (and unusable) for many years, was air-conditioned, the leaking windows in the ceiling were fixed, and a raised floor was installed to accommodate computer installation. A variety of computer equipment has been installed, including one computer with a full UNIX operating system, a Computervision system, and many microcomputers. This area is dedicated to research activities.

Room 7-321, which became available to the Department two years ago following the partitioning of one of the Course XIII-A project rooms, has also been refurbished and air-conditioned. This is a room with high visibility (on the balcony of the Building 7 lobby), and it will be dedicated to teaching

activities that focus on the use of computers, especially computer-aided design. It is connected to the research area on the fourth floor of Building 5 by a conduit that will allow the installation of high-rate communications. The Department has requested that Room 7-321 be designated as a teaching cluster for Project Athena. A connection to the MIT communications spine has not yet been made.

Other facility changes include the following:

- The Ocean Engineering Lounge, Room 5-314, was renovated and refurnished. A basic kitchen facility was installed.
- The former Ocean Engineering Design Laboratory, Room 5-220, and the Offshore Structural Design Laboratory, Room 5-218, are being converted into new faculty office space. The work will be completed this summer.
- The Offshore Structural Design Laboratory was moved to Room 5-207, a previously underutilized basement room, which it shares with the Department's Ocean Acoustics Laboratory.
- A small area in the outer part of Room 5-207, which was previously used for long-term storage, was converted into an office for the International Shipping Club, the student organization in Course XIII-B.

#### CONFERENCES SPONSORED

The Department sponsored or co-sponsored the following conferences during the year, bringing together world experts in several fields of importance to ocean engineering:

The First International Workshop on Water Waves and Floating Bodies was organized by Professor J. Nicholas Newman, with financial support from the National Science Foundation. About 50 persons from many countries attended the workshop, which was held at MIT February 16-19. Several MIT graduate students also participated. It is expected to be an annual event, with the next one to be held in the United Kingdom.

A one-day workshop on Vehicle Crashworthiness Optimization was organized by Professor Tomasz Wierzbicki and held in Detroit on April 21. There were about 30 participants, mostly from the automotive industry in the United States and Europe. The workshop was scheduled so that it would just precede the 6th International Vehicle Structural Mechanics Conference, which was also held in Detroit. The industry experts represented companies that are current or potential members of a consortium sponsoring research at MIT on vehicle crashworthiness. Professor Wierzbicki is the principal investigator on the project.

In collaboration with the MIT Center for Transportation Studies, Associate Professor Henry S. Marcus organized a one-day technical seminar, International Liner Freight Transportation, on June 3. There were fifty attendees, mostly representing companies that provide or heavily use international freight transportation.

Marine Computers '86 was held in Burlington, MA, April 17-19. It was sponsored by the New England Section of the Society of Naval Architects and Marine Engineers. The primary organizers were Associate Professor Michael S. Triantafyllou, Assistant Professor Nicholas M. Patrikalakis, Professor A. Douglas Carmichael and Professor Clark Graham. Over 200 people attended the conference, which featured current developments in the use of computers in marine industries.

#### ROBERT BRUCE WALLACE ACADEMIC PRIZE AND LECTURE

The fifth Robert Bruce Wallace Academic Prize, for the 1986-87 academic year, will be awarded to Mr. Lee A. Denson. This prize was endowed by Albert H. and Marion W. Chatfield in honor of Mrs. Chatfield's father, Robert Bruce Wallace, Class of 1898. The fifth Robert Bruce Wallace Lecture was presented by Dr. John A. Mercier on November 18, 1985; his subject was "The Hutton Tension-Leg-Platform Project."

T. FRANCIS OGILVIE

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## Artificial Intelligence Laboratory

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The primary goal of the Artificial Intelligence Laboratory is to understand how computers can be made to exhibit intelligence. Two corollary goals are to make computers more useful and to understand certain aspects of human intelligence. Current research in the Laboratory includes work on robotics, vision, natural language, learning, reasoning and problem solving, deep expert systems, computer-aided programming, intelligent supercomputing, and music cognition.

Professor Patrick H. Winston works on the problem of learning from precedents. Professor Marvin Minsky develops general theories of intelligence and knowledge representation. Professor Robert C. Berwick studies fundamental issues in natural language, including syntactic and semantic acquisition. Dr. J. Michael Brady, Professor W. Eric L. Grimson, Professor Berthold K. P. Horn, Professor Tomaso Poggio, and Professor Shimon Ullman do research in computer vision. Professor Rodney A. Brooks, Professor John M. Hollerbach, Professor Tomás Lozano-Pérez, Professor Warren Seering, and Dr. J. Kenneth Salisbury work on other aspects of Robotics. Professor Randall Davis and Dr. Howard E. Shrobe work on deep expert systems that use both functional and physical models. Dr. Charles Rich and Dr. Richard C. Waters explore the creation of intelligent programming environments. Professor Carl E. Hewitt studies distributed problem-solving and parallel computation. Professor Thomas F. Knight develops the Cross-Omega Connection Machine, a special-purpose machine for concurrently manipulating knowledge stored in semantic nets and image arrays. Professor Gerald J. Sussman, with Professor Harold Abelson of the Laboratory for Computer Science, leads a major new research program aimed, in part, at creating sophisticated problem-solving partners for people working in a variety of science and engineering disciplines.

The Laboratory's 166 members include 15 faculty members, 4 academic staff, 52 research and support staff, and 95 graduate students active in research activities funded by the Defense Advanced Research Projects Agency, System Development Foundation, Office of Naval Research, Air Force Office of Sponsored Research, National Science Foundation, Digital Equipment Corporation, General Motors Research Laboratories, General Electric Company, NATO, Standard Oil Company, Schlumberger, International Business Machines, Martin Marietta, Wang Laboratories, Hughes Research Laboratories, Sperry, Exxon Research and Development Company, NASA, John Deere Foundation, and General Dynamics.

### ROBOTICS

The Laboratory's robotics researchers investigate the principles underlying the intelligent connection of perception to action. Autonomous robots must be able to construct a model of the environment from sensory input; to plan and to control the use of arms, hands, and locomotion systems; and to coordinate perception, reasoning, and action activities to achieve goals in changing, uncertain, and unstructured worlds. Researchers in the Laboratory direct efforts in the following areas: reliable locomotion, model-building, planning in the face of uncertainty, and refined, compliant manipulator control.

### Mobile Robots

Professor Brooks, Anita M. Flynn, Jonathan H. Connell, and other members of the Mobile Robotics group investigate methods for building robust control systems for mobile robots that operate autonomously and in real time in changing, unpredictable environments. The group completed their first mobile robot, named Allen, in January, 1986. Off-board LISP machines connected by a television-and-radio link to on-board stereo video cameras and ultrasonic range sensors provide the computational power necessary to control the robot. Allen spends much of his time exploring Laboratory space, avoiding collisions with inanimate objects and with people moving through the environment. Exploring is the precursor phase to map building, where the robot will build maps of its environment by combining many noisy sensor measurements taken over a period of time.

The research group designed and is finishing construction of a second mobile robot, which features a lightweight arm and a 32-processor parallel processor on board. The arm's large workspace will enable the robot to pick up objects from both table tops and floors.

Professor Brooks has defined several levels of behavioral competence that he believes are necessary for a robust mobile robot control system. As a robot becomes more competent, more processor power is added, leaving existing processors unaware of higher-level control layers. The resulting multi-processor architecture, called a subsumption architecture, is unlike other current multi-processor designs because there is no shared memory or expensive switch, and all processors are completely asynchronous. Professor Brooks, Ms. Flynn, and Mr. Connell implemented a subsumption architecture control system for the first robot and are implementing an improved system directly in the on-board parallel processor of the second robot. Peter W. Cudhea is investigating how the subsumption architecture can implement robot control systems with multiple but coordinated goals.

William Y-P. Lim continues to work on model-based vision. The goal is to develop vision algorithms for selecting naturally occurring objects as landmarks—objects that may be recognized from different viewpoints—to enable mobile robots to build maps of their environments. Central problems include finding the right multi-scale representation, the right scheme for indexing the model database by key features, and suitable matching algorithms.

Daniel A. Frost implemented a path planner for a mobile robot in a known environment. The path planner treats all walls and obstacles as repulsive forces. Mr. Frost developed a way to represent the resulting potential fields in tables small enough to be carried on board the robot. By comparing sensor readings to these tables, the robot can identify unexpected situations.

#### Planning for Collision-Free, Compliant, and Grasping Motions

Professor Lozano-Pérez leads research in the area of robot motion planning in the presence of uncertainty. In collaboration with Professor Matthew T. Mason of Carnegie-Mellon University and Dr. Russell H. Taylor of IBM, Professor Lozano-Pérez developed a method for automatically planning compliant motions for assembly robots.

Michael A. Erdmann extended the approach to incorporate a detailed model of frictional interactions among objects. Mr. Erdmann also showed how to separate the issues of attaining a goal from recognizing that the goal has been attained. Steven Buckley implemented a related method of predicting the possible outcomes of a sequence of compliant motion commands in the presence of position uncertainty.

Bruce R. Donald extended the work in two new directions. One extension allows uncertainty in the shape as well as the position of the objects being manipulated. The other extension allows a more general class of motion plans that are guaranteed either to achieve the goal or to detect failure when it occurs.

Professor Lozano-Pérez and his associates developed a variety of algorithms that use configuration space to plan collision-free motions. Mr. Donald implemented the first program able to plan motions involving both the three rotational degrees of freedom and the three translational degrees of freedom of a moving object. Professor Lozano-Pérez implemented a simple, fast path planner that plans motions of robots with revolute joints in crowded environments. Mr. Erdmann and Professor Lozano-Pérez implemented a planner that uses configuration space/time to plan coordinated motions for multiple manipulators.

John F. Canny continued work on a new representation of configuration space based on quaternions, in which the constraints on the motion of a polyhedral object moving among polyhedral obstacles become low-order polynomials. Using this new representation, Mr. Canny developed efficient collision-detection algorithms for polyhedral objects undergoing simultaneous translation and rotation. Mr. Canny also developed a general algorithm for constructing a one-dimensional subset, or roadmap, of semi-algebraic sets and applied it to finding collision-free paths in high dimensional configuration spaces.

Professor Lozano-Pérez, Patrick A. O'Donnell, Joseph L. Jones, and Dr. Emmanuel Mazer are implementing an integrated hand-eye system to do assembly in unstructured environments. The system will recognize objects placed randomly on a table, choose an assembly sequence, plan a safe grasp on each object, plan a collision-free motion to grasp each object, and take each object to its destination. Individual pieces of the system include: a polyhedral modeling system developed by Dr. Alain Lanusse, an object-recognition system developed by Professors Grimson and Lozano-Pérez, and a path planner developed by Professor Lozano-Pérez.

#### Robot and Human Arms and Hands

Professor Hollerbach's research involves two major thrusts: the kinematics, dynamics, and control of human arms and robot manipulators; and the grasping, tactile sensing, and haptics of human hands and multi-fingered robot hands.

The MIT Serial Link Direct Drive Arm, the focus of Professor Hollerbach's manipulator research, is operational due in large part to the efforts of Chae Hun An and Christopher G. Atkeson. In particular, Mr. An implemented a torque control loop that allows precise joint torque control. One of the few manipulators in existence able to test advanced control methodologies, the MIT Serial Link Direct Drive Arm is the first to demonstrate dynamic estimation of link inertial parameters, feedforward control during high-speed motions, and trajectory learning.

Understanding dynamic arm movements requires precise knowledge of the inertial parameters of each manipulator link—the mass, the center of mass, and the moments of inertia of each link. Few dynamic models exist because robots are usually designed only for kinematic parameters, not for dynamic parameters, and because most robot controllers are not model based. Mr. An, Mr. Atkeson, and Professor Hollerbach devised a formalism that allows the estimation of inertial parameters during ordinary movement by relating joint torque readings to joint velocities and accelerations. These parameters are more accurate than a set of parameters previously estimated for the arm by CAD modeling, lending support to the viability of this technique. Using the dynamically estimated model, Mr. An, Mr. Atkeson, and Professor

Hollerbach also tested feedforward control strategies, finding that feedforward control improves trajectory following over control strategies that involve simplified models or no models at all.

Mr. Atkeson formulated an optimal strategy for trajectory learning, in which the torque output for a repeated motion is adjusted offline after each iteration to reduce trajectory errors. Because no analytical model for a robot is ever exact, there are inevitable trajectory errors that can be reduced by feedback or that can be eliminated almost completely by locally modifying the previous repetition's torque output. Mr. Atkeson showed that for the best convergence the trajectory errors should be run through the robot model to predict the corrective torques and that better models lead to faster convergence. Thus trajectory learning does not obviate the need for good models. With Joseph A. McIntyre, Mr. Atkeson used the Direct Drive Arm to demonstrate rapid convergence to almost no trajectory errors after just three repetitions.

Using a Watsmart System, Professor Hollerbach and David J. Bennett began an investigation of automatic kinematic calibration of a PUMA 600 Arm. This opto-electronic movement-monitoring system tracks in real time, with accuracies of 1-2mm, LEDs attached to the manipulator endpoint. There is a need for automatic calibration because current methods of kinematic calibration require extensive human interaction and do not operate in real time. Preliminary results indicate a rapid estimation of the kinematic parameters.

Professor Hollerbach believes that future general-purpose manipulators will be redundant with seven or more degrees of freedom, in order to avoid obstacles and joint limits, to eliminate internal singularities, and to distribute joint torque loading. After investigating a variety of possible geometries for redundant manipulators, he concluded that a spherical shoulder arm similar to the human arm is the optimal kinematic design. Professor Hollerbach has been investigating global optimization strategies for redundancy resolution because local optimization strategies are prone to disaster. He developed a formalism for global kinematic optimization, which is being tested in collaboration with Daniel Martin of Scientific Systems, Inc., and a formalism for global dynamic optimization, which is being tested by Ki Choon Suh.

The MIT Artificial Intelligence Laboratory/University of Utah Center for Engineering Design hand was completed in the fall. The hand, designed in collaboration with Professors Steven Jacobsen and John Wood of the University of Utah, has four fingers operated by tendons. To control the hand, David M. Siegel, Sundar Narasimhan, and Scott A. Jones constructed a multiprocessor system based on a Motorola 68000 chip and a multi-bus, where one microprocessor controls each finger and its eight tendons. They are constructing a motion-sequence editor that will be used to manipulate the hand. Professor Hollerbach and Mr. Narasimhan formulated and are implementing an efficient algorithm for Cartesian position and force control of a grasped object in the Utah/MIT hand. This algorithm circumvents the computational complexity of previous formulations that prevented an on-line utilization.

Mr. Siegel, Inaki H. Garabieta, and Professor Hollerbach designed and tested large-array tactile sensors to be used on the hand. The arrays are defined by conductive strips screened onto thin rubber sheets. An electronic circuit detects capacitance change due to decreased distance between conductive strips from pressure deformation.

Dr. Salisbury's research is concerned with the design, control, and programming of articulated hands as a means for increasing robot dexterity and adaptability. Fundamental to his approach is the study of the underlying mechanics of manipulation and sensing with multiple degrees-of-freedom end effectors. He has developed a comprehensive laboratory environment for experimentation with the Salisbury three-finger hand. This includes extensive control software for commanding finger trajectories under position, force, and stiffness control, as well as analytical software for servo experimentation.

The system is implemented on a three-level hierarchy of computers for exercising command and control over the hand. The lowest level of control uses a dozen microprocessors to servo individual tendon motions. The middle level of control uses a VAX 11/750 computer to coordinate tendon motions, implement force and stiffness control, and provide reflex actions in response to definable conditions. The highest level of control is a LISP-based command environment. This system coordinates the finger movements needed to manipulate objects, and monitors and reacts to events occurring during hand operation.

Dr. Salisbury is integrating the Salisbury hand control system with the grasp-planning system developed by Van-Duc Nguyen. This planner enumerates stable grasping configurations for general polyhedra, then selects the optimum finger stiffnesses required to establish a robust grasp. In its initial demonstration, the system identified a number of non-intuitive grasping configurations.

David L. Brock successfully miniaturized a six-axis force-sensing fingertip. This unique fingertip gathers geometric information about contacts with the environment; for example, probing unknown objects to determine their shape and location. Dr. Salisbury plans to mount three such fingertips on the hand in order to gather simultaneous contact information needed for consistency checks on planned manipulations. The data will also be used with the Grimson/Lozano-Pérez recognition algorithm to identify grasped objects and to refine their locations relative to the hand.

Mr. Brock also completed an analysis of the use of controlled slip to perform motions within the hand. The analysis establishes the basic mechanical principles required to plan automatically motions requiring inter-finger slipping.

Dr. Salisbury is designing a high-performance lightweight manipulator for possible connection to the Salisbury hand. William Townsend developed an extensive model of transmission friction which is being used to improve the hand's servo performance as well as to understand the arm design tradeoffs imposed by friction. Mr. Townsend also developed a passive five-degrees-of-freedom prototype wrist and arm mechanism. The device is currently employed to support and orient the hand during experimentation. Benjamin Paul developed a comprehensive model of low-speed torque characteristics of a brushless motor to support the arm design effort.

Professor Seering and his research group work on control concepts for light, flexible arms and on methods for directing a robot's response to sensed inputs. They also study the tasks that robots might perform and create strategies for directing them to do so.

Several of Professor Seering's students are involved with teaching computers to design mechanical systems. This work includes developing algorithms to create new designs and to choose system components that meet design specifications.

## VISION

Vision is the process of recovering from images a description of what is present in the world and where it is. This involves understanding how subsystems, such as edge detection, stereo, motion, texture, and color modules, can recover part of the visual information available. It also involves understanding how the output of the modules can be integrated and used to recognize shapes and objects. At another level, the problem of vision involves discovering efficient algorithms for performing visual processing and designing appropriate architectures to implement them. These areas—theoretical, algorithmic, and architectural—are the subject of intensive study by the various research groups in the Laboratory.

### The Regularization Approach

Professor Poggio, in collaboration with Dr. Alessandro Verri and Dr. Vincent Torre, applied regularization analysis to problems of early vision that are ill-posed in the sense of Hadamard. Regularization theory represents a new theoretical framework for early vision that unifies most of the past results and suggests several new ones. As proposed by Professor Poggio and Dr. Torre, edge detection, when defined as a problem of numerical differentiation, is an ill-posed problem. Using standard regularization theory, the problem can be regularized. The regularized solution is then the solution to a variational principle.

In the case of non-exact image data Professor Poggio, Harold L. Voorhees, and Dr. Alan L. Yuille have proven three things: that this variational principle leads to a convolution filter for the problem of one-dimensional edge detection; that the form of this filter—a spline—is very similar to the Gaussian filter; and that the regularizing parameter  $\lambda$  in the variational principle effectively controls the scale of the filter. David Geiger and Professor Poggio used methods from regularizing theories for finding the optimal value of the regularizing parameter  $\lambda$  as a function of signal-to-noise ratio in the image. Mr. Voorhees and Professor Poggio are developing methods to determine the physical origins of edges in the image from an analysis of the texture. Dr. James J. Little is also developing techniques to detect texture boundaries, using multi-scale analysis of edge densities.

Another problem that can be approached with regularization techniques is the computation of spectral reflectance of surfaces. A basic goal of biological color vision is to recover the invariant spectral reflectance properties of an object's surface. Anya Hurlbert and Professor Poggio are developing a regularization algorithm in which two constraining assumptions allow the decomposition of the intensity array into surface reflectance and source illumination: the single-source assumption, which states that the spatial variation of the source illumination is the same for each wavelength channel; and the spatial regularization assumption, which states that the spatial variation of the effective source illumination is slower than that of the surface reflectance.

Also consistent with regularization is the study of Dr. Norberto Grzywacz and Dr. Yuille on constraints for defining a cost function for motion correspondence. They showed these cost functions can be minimized, quickly and efficiently, by parallel analog networks.

Dr. Little and Dr. Heinrich Bülthoff are developing fast algorithms to measure the optical flow and its discontinuities. The algorithms will be part of the Vision Machine to be implemented on the Connection Machine.

Both standard regularization theory and Markov Random Field models lead to algorithms that map directly into parallel architectures of the fine-grained type represented by the Connection Machine system.

Following this line of thought, Michael Drumheller and Professor Poggio implemented a parallel stereo algorithm on a Connection Machine (in collaboration with employees of Thinking Machines Corporation). The algorithm runs efficiently on real images in under a second.

Standard regularization also leads to the unconventional parallel architecture of analog networks proposed by Professor Poggio and Dr. Christof Koch. James Hutchinson explored the feasibility of building analog silicon devices for some of

the early vision problems. He investigated issues of noise and precision and concluded that the technology is promising and feasible. John G. Harris devised new, efficient analog networks for solving the surface reconstruction problem. His work suggests not only a new generation of hardware but also efficient algorithms on standard machines.

Hybrid networks—both digital and analog—have been proposed by Dr. Marroquin and Professor Poggio to implement Markov Random Field based algorithms to solve early vision problems such as surface reconstruction, segmentation, and stereo. Dr. Koch and Dr. Yuille have analyzed the use of nonlinear analog networks to solve the same class of problems and suggested hybrid architectures without a stochastic component.

Dr. Yuille also developed an alternative, non-regularization, approach to color vision (similar to work by Maloney and Wandell at Stanford). The surface reflectance and the source illumination are approximated by a set of three basic functions. With four color input receptors, the color boundaries between objects can be found. The surface reflectance can be solved for at these boundaries, and the color of the object determined.

### Fusion and Beyond

To push beyond early vision, information from different sources must be integrated to form coherent, unified descriptions. The problem of fusing information from different early vision modules is being attacked by Mr. Gamble, Dr. Verri, and Professor Poggio by using the theory of coupled Markov Random Fields. A feasibility study is under way using synthetic computer graphic images. Efficient implementations on the Connection Machine are planned.

The appearance of objects in an image depends on illumination, surface orientation, and surface properties such as spectral reflectance and texture. Each of the vision modules provides independent descriptions of image events. An interpretation of the physical origin of edges can be determined by examining the consistency of the output of these modules. Dr. Little and Dr. Verri are developing methods for labeling edges based on the interaction among the modules.

Professor Poggio and his associates are developing a new vision system to help study the problems of fusion and visual recognition. The device providing input to the system is an artificial eye-head system with two movable, computer controlled CCD cameras. Michael Villalba is extending the system for the needs of the Vision Machine. Dr. Yuille and Mr. Geiger are developing an algorithm for the eye-head system for stereo matching guided by eye-movements and change of focus. This algorithm could be implemented by the eye-head system. It also suggests a new approach to the fusion of stereo and motion information.

Also underway is a study of the processing of visual information beyond the creation of early representations. The processes of recognition, manipulation, navigation, and abstract reasoning often rely on detecting visually abstract shape properties and spatial relations. Professor Ullman has proposed that the perception of spatial relations is achieved by the application of visual routines—sequences of basic spatial operations—to the early representations. Some of the required basic operations include boundary tracing, area coloring, and indexing (the selection of the scene locations that are most relevant at a given time). The implementations of these basic spatial operations must be efficient to cope in real time with the potential complexity of scenes. James V. Mahoney and Professor Ullman are developing specialized early visual representations to support fast indexing, tracing, and coloring. Substantial performance gains are achieved by defining the basic operations to operate on extended chunks of the image, instead of individual pixels. Mr. Mahoney defined efficient processes for computing a variety of extended image chunks in early vision. These parallel processes have been implemented on LISP machines; they will also be implemented and tested on the Connection Machine.

### Stereo Vision

The problem of stereo vision can be divided into three parts: detecting and extracting features in each of the two images, matching the features of one image with those of the second, and converting matched features into depth values. Professor Grimson leads research that centers on the first two parts.

The detection of corners and vertices in images is being investigated by Michael A. Gennert, who is adapting edge detection methods to solve this problem. The difficulty with using existing edge detectors, such as the Canny operator or the Laplacian of a Gaussian operator, at corners and vertices is that many of the assumptions behind these operators apply only to infinite, straight edges. An edge detector that relies on truncating or windowing an edge operator is not subject to these limitations.

Mr. Gennert also proposed a new computational framework for understanding the problem of stereo vision. He offers a rigorous new definition of the assumptions, constraints, and principles underpinning the performance of existing stereo systems. He is developing image intensity matching and stereo algorithms based upon this framework.

David J. Braunegg worked on improvements to the Marr-Poggio-Grimson stereo algorithm. He investigated new methods for validating and disambiguating matches between features extracted from the two images. In a separate project, Professor Grimson investigated new constraints and search methods for finding matches.

A further step in deepening our understanding of stereo vision involves integrating other visual cues with the stereo process. Based on earlier work by Professor Grimson, Richard P. Wildes has been investigating the problem of integrating shading information with stereo processing. By using data from a stereo matcher, it is possible to determine the reflective parameters of the surface material covering an object, provided it belongs to a general class of materials and the position of the light source is known. Mr. Wildes is developing a technique for constructing dense surface representations that applies a modified version of a shape-from-shading algorithm developed by Professor Horn and Dr. Michael Brooks to both reflectance and stereo data.

Professor Grimson and Mr. Braunnegg also worked on the problem of integrating stereo algorithms with the Laboratory's mobile robot project.

### Recognition

Professors Grimson and Lozano-Pérez have been exploring visual processes beyond the early modules by developing a system capable of recognizing objects using polyhedral models of known objects and information about the position and surface orientation of a few points. Their system determines both an object's identity and orientation, despite considerable object overlap. Research has continued along a number of fronts.

Daniel P. Huttenlocher is implementing a system for recognizing objects with three-dimensional positional uncertainty, given a single two-dimensional view. The current focus is recognition of flat objects with arbitrary three-dimensional position and orientation, using edge contours. The approach is based on finding a small number of distinguished points in an image. Three of these points can be used to determine the position and orientation of a given object in space, if that object were actually to correspond to the image points. The object model can then be projected into the image and compared with the edge contours, in order to determine if the object corresponds to the image. The distinguished points are located in the image using local edge groupings such as protrusions, notches, straight segments, and closed regular regions. Other kinds of information such as color and texture could also be used to provide a richer set of distinguished points.

David T. Clemens investigated the tradeoffs between hypothesis-driven and data-driven recognition techniques, both examining the theoretical complexity of different approaches to recognition and developing a series of techniques for recognizing arbitrarily-shaped two-dimensional objects. As part of this problem, Mr. Clemens devised methods for automatically extracting appropriate representations of the shapes of curves from noisy data.

Gil J. Ettinger is developing a model-based recognition system which integrates a curvature primal sketch representation (based on Brady's work) with a constrained search recognition engine (based on the work of Grimson and Lozano-Pérez). The system benefits from the rich vocabulary of the representation and the spatial constraints of the object features in order to achieve the goals of robustness, efficiency, and extensibility. Special emphasis is placed on the automatic determination of object sub-parts which allows the system to handle variations in sub-part parameters and to construct a model library for effective indexing of candidate objects. The resulting system exhibits a hierarchical nature by using a multi-scale representation and a structural as well as scalar hierarchy in its recognition engine.

David Jacobs is investigating problems associated with the recognition of objects from large libraries of possible objects. He is concerned with the structuring of libraries of object representations for rapid recognition and with the automatic extraction of the best features to be used for recognition.

Todd A. Cass is considering how parallel architectures, in particular how the Connection Machine, can be harnessed to help object recognition. To this end, he is studying both theoretical issues of search complexity in parallel recognition and practical Connection Machine algorithms for recognition.

### Shape Representation

Eric Saund is working on representations of shape for later vision which may support recognition, categorization, and comparison of objects based on their geometrical properties. The goal of this work is to build a vocabulary of symbolic shape descriptors at various levels of abstraction. This vocabulary of symbols, together with rules about how the symbols may be combined, will comprise knowledge about shape in a particular object domain, such as the world of hand tools. An implementation of this approach in a one-dimensional shape world indicates that scale-space filtering is a useful step in the extraction of suitable symbolic primitives and that more abstract descriptors may be defined as configurations of primitive features over scale-space.

In the course of this work, Mr. Saund developed a method for performing a form of data compression called dimensionality reduction. The approach extends the back-propagation method for training Parallel Distributed Processing networks of simple computing elements in order to encode knowledge of constraint in vector-valued data. Dimensionality reduction is useful in extracting parameterized descriptions for shape categories. For example, it will allow us to define as part of the shape of a pair of pliers, the parameter, *amount jaws are open*, an obvious shape category.



## Laser Ranging

Dr. Philippe Brou broadened the range of services provided by the laser system by adding a software interface. He has begun to assemble a second laser work station. One new use of the technology is in the field of assembly, where the laser system allows a robot to identify the position of an object in its hand.

## NATURAL LANGUAGE

Professor Berwick and his associates are adding a computational dimension to linguistic theory. Their work is based on the assumption that both computational and linguistic viewpoints are necessary for an adequate understanding of natural language processing. Linguistic theory uncovers many of the natural constraints of human language. But studies of the computational complexity of grammars teach us that other constraints are needed. Accordingly, Professor Berwick and his students focus their research on the computational side of government and binding theory, a theory that is both modular and principle-based, reducing much of the variation between languages to differences in a small set of parameters. This approach promises to yield processing systems that are easier to change from language to language.

George E. Barton continued the computational analysis of the so-called two-level model of morphological processing, isolating spelling uncertainty and dictionary navigation as two different sources of processing complexity. He has shown that spelling uncertainty alone is sufficient to allow computationally difficult situations to arise. He has also conceived and implemented an improved dictionary representation that in practice sharply reduces dictionary navigation complexity. In addition, Mr. Barton is investigating a constraint-propagation method for two-level processing. Unlike the original processing method, the constraint-propagation method does not do expensive combinatorial search and cannot solve some unnaturally difficult problems that the two-level model fails to exclude. Mr. Barton plans to investigate whether the new method is sufficiently powerful for all cases that arise in practice.

Eric S. Ristad is investigating the computational properties of the Generalized Phrase-Structure Grammar formalism. Mr. Ristad has used tools of computational complexity theory to show that generalized phrase structure grammar (GPSG) is computationally intractable as it stands. Using insights from the complexity analysis, he developed a revised version of the theory (RGPSG), which exhibits greatly improved computational properties and is more constrained linguistically.

Professor Berwick, Mr. Barton, and Mr. Ristad have collected their joint work on the complexity analysis of natural language into a book to be published by The MIT Press.

Bonnie J. Dorr is working with Professor Berwick on a principle-based computational model of natural language translation. She investigated some of the universal principles that hold across languages as well as the parameters of variations that distinguish languages. She is now developing a translation system based on the results of this investigation. The translation system includes three components, a parser, a lexical replacement module, and a generator, each of which relies on the principles of current grammatical theory. A goal of the approach is that languages can be added by changing the parameters and principles instead of redesigning the system. Currently the system can translate simple sentences bidirectionally between Spanish and English.

Sandiway Fong completed his investigation of set-based representation for conjunctive sentences, traditionally considered problematic for natural language processors. He constructed a PROLOG implementation of his processing machinery. He also developed a method of analyzing the computational complexity of logic programs written in languages such as PROLOG.

The dictionary (or lexicon) plays a key role in government-binding theory as well as other current linguistic theories. Two projects draw on recent developments in the theory of the lexicon.

Michael B. Kashket completed an early version of a parsing system for Warlpiri, an Australian aboriginal language that exhibits free word order. His parser uses linguistic constraints to interpret the highly permutable sentences, in contrast to other methods that would spell out the many possible sequences in separate rules. The key component in the interpretation is Case theory, which dictates the relation between the words and phrases in the surface sentence and the corresponding syntactic categories in the underlying representation. The information that guides the mapping is stored in the lexicon, in entries that are applicable to single words and classes of words.

Michael R. Brent is investigating the design of a sentence generation system that will map from a stylized representation of meaning to a set of sentences that directly express the meaning. The mapping process will be driven by the syntactic parameters and lexical-conceptual structures that form a theoretical description of the language.

## LEARNING

Professor Winston's theory of reasoning by analogy consists of the following parts: an English-understanding module, developed and implemented by Boris Katz, that converts prepared text into relations in a semantic network; a cause-dominated matcher that finds the best possible correspondences according to the causal framework determined by the situations themselves; an analogizing module that reaches conclusions about a given situation by using a remembered precedent; and a rule builder that constructs if-then rules. Professor Winston extended the theory to the problem of learning what things look like from functional definitions, prior knowledge, and particular examples.

Dr. Kirsh has been developing a theory of causal representation in an effort to improve cause-dominating matching. The key idea is that objects can be represented as sets of causal powers that can be turned on or off depending on background conditions, *ceteris paribus* conditions, the boundary conditions of their current context, and initial conditions. The theory focuses on how these various conditions affect the process of switching powers on and off, thus determining the deep structure of a causal situation. The analogy system is expected to perform better because it will have a better understanding of how the causal structure of a situation varies with context.

In a parallel effort, Richard J. Doyle is developing a learning system that constructs and refines causal models of physical devices such as cameras and thermostats. Given a timeline description of the observable behavior of a device, Mr. Doyle's learning system forms a model of the device that describes causal relations which can account for the behavior. The system utilizes a theory of mechanisms in physical systems described within a representation for causality developed by Mr. Doyle.

Robert J. Hall has been investigating how to learn structure/function relationships from example designs. The essence of the technique, Learning by Failing to Explain, is to use current knowledge to explain familiar parts of the example, in order to isolate those aspects which are new. The application domains have been digital circuit design and the design of simple gear mechanisms, although the technique should be more widely applicable; for example, the same technique should apply to learning implementation rules for automatic programming.

Richard H. Lathrop is studying the role of abstraction in learning and reasoning. He implemented a preliminary program that converts a highly detailed room-and-thermostat model into more and more abstract, less and less detailed descriptions, ending with a simple switch triggered by room temperature that turns the furnace on and off. An implementation of the underlying ideas applied to VLSI micro-circuitry demonstrated the automatic inference of low-level hierarchy and explored the use of design precedents to capture and re-use design expertise. Applied to molecular biology protein super-secondary structure recognition, a similar program hypothesized a mononucleotide binding fold structural location for the class of proteins, aminoacyl t-RNA synthetases.

Kenneth W. Haase is working on programs that discover and use concepts in a variety of technical domains. These programs, called *inquisitive systems* learn by synthesizing new representations. Given an initial vocabulary for some domain, they use the empirical properties of the vocabulary to construct new terms and definitions for describing and reasoning in the domain. These new terms—in addition to their practical utility in dealing with the domain—can serve as a new base of vocabulary for further cycles of discovery and extension.

## REASONING AND PROBLEM SOLVING

John D. Batali developed a computational theory of rational action, implemented in a program called PRAXIS, which responds automatically to situations by performing actions, planning, executing plans, and by keeping track of what is going on. Occasionally PRAXIS finds reasons to modify its automatic responses, or will interrupt its automatic activity to perform more careful deliberation about what it should be doing. In deciding upon an appropriate response for a situation, PRAXIS exploits similarities between the new situation and any previous situations for which PRAXIS was able to find a good response. If a previous situation was similar enough to the new one, then the response used previously will probably be effective again.

Philip E. Agre is developing a new theory of planning based on the concept of a routine. By studying in detail unproblematic activities, such as making breakfast, Mr. Agre has extracted a set of routines which capture important regularities in the way intelligent agents interact with the world. The result is a more realistic and computationally tractable alternative to customary theories of planning that is easily implementable on massively parallel hardware.

David A. McAllester is constructing a knowledge representation system for conceptual mathematics. The system, known as ONTIC, includes a new inheritance mechanism called semantic modulation. Semantic modulation is used to invoke automatically a large knowledge base (lemma library) when checking mathematical statements. The inheritance mechanism is a form of theorem proving which is guaranteed to terminate in  $n \log(n)$  time where  $n$  is the size of the knowledge base. The ONTIC system incorporates the axioms of ZFC set theory and can be used to define terminology and verify arguments in any branch of mathematics. Using ONTIC's formal language, Mr. McAllester has written a three thousand

line mathematical book that starts with the axioms of ZFC and ends with a proof of the Stone representation theorem. A machine verification of all theorems and lemmas in this book is nearly completed.

Ramin Zabih is exploring interpretation strategies for a language with automatic backtracking. The language is a simple extension to pure LISP that allows non-deterministic choice. He is writing a number of interpreters for this language that use different dependency-directed search techniques. He is also investigating the possibility that search problems expressed in this language can be compiled into a conjunctive normal form propositional formula, where the existence of a solution to the search problem is equivalent to the satisfiability of the propositional formula. If search problems can be so compiled into propositional formulas then general search problems can be solved using mechanisms for determining propositional satisfiability.

On another front, Dr. Fanya S. Montalvo is working on the problem of diagram understanding, a way of communicating with a computer graphically, in a manner analogous to the way natural language understanding permits verbal communication. This area centers on the overlap between computer vision and computer graphics, that is, dealing with questions about the representation of visual knowledge. The work involves building a visible vocabulary and a way of attaching diagrams to specific applications; and testing the vocabulary using humans in the graphic interaction loop.

## DEEP EXPERT SYSTEMS

Professor Davis, Dr. Shrobe, and their associates are building an expert system that uses knowledge about structure, function, and causality to diagnose faults in digital electronic hardware. Previous expert systems have typically been built from large collections of empirical associations. This work relies instead on a detailed model of the structure and function of a device, allowing it to reason about how the device works and how it fails, in a manner similar to an experienced engineer.

Building and using such a model represents an important advance in the art of expert systems construction, because it provides the system with a more fundamental understanding of the device than is possible using the traditional approach. While the current work considers digital circuits because of their tractability and significance, the larger concern is that of reasoning about devices in general, understanding how they work and how they fail.

The work has explored multiple uses of descriptions of structure and behavior. These descriptions are used for a range of tasks, including candidate generation (determining which components of a circuit can account for observed malfunction), designing tests to distinguish between candidates, and test programming (designing a comprehensive collection of tests that verify correct device operation).

The approach is capable of handling a wide range of faults, including such things as bridges and errors of incorrect assembly, faults that are not handled by traditional approaches to troubleshooting.

Walter C. Hamscher extended these techniques to apply to more complex designs that include memory and behavior over time. He showed that the problem of diagnosing circuits with memory is fundamentally underconstrained, and he explored the utility of several different behavioral abstractions as ways of constraining the problem.

Harold J. Haig designed and implemented a hardware description language based around the vocabulary typically used by hardware architects and designers, making the resulting language compact and readable.

Mark H. Shirley is building a system capable of generating diagnostics from a circuit description. Unlike traditional programs that work with gate-level descriptions, this system uses knowledge about how to test high-level components (such as ALU's or memories) and knowledge about standard patterns of usage of devices (such as how an I/O interface is typically used) to develop high-level plans for device testing. The result will be a system that is capable of generating tests for devices considerably more complicated than those handled by existing test generators. A paper describing this work was designated "Best Paper" in the Engineering Track of the 1986 Conference of the American Association for Artificial Intelligence.

Peng Wu is developing a system that functions as an assistant in design for testability (DFT). Most work on DFT approaches the problem by requiring the designer to use throughout the circuit techniques like level-sensitive scan design that guarantee testability; some work has suggested exhaustive addition of built-in testing hardware. In either case indiscriminate application of these techniques comes at a high price in added hardware. A central theme of Mr. Wu's work is that techniques to ensure testability should be used only in those places that are known to be inaccessible to a competent test design system. His program thus takes as input the circuit design, the results of Mr. Shirley's program, and pays particular attention to the places where that program failed and the reasons why it failed. Those specific failures become the testability goals that are the focus of Mr. Wu's program, which then will choose DFT techniques appropriate to the specific situation.

Brian C. Williams is working on a novel approach to circuit design. Where traditional systems have been based on a library of standard designs, this system focuses on design based on fundamental principles of qualitative physics and

qualitative mathematics. A design is constructed using a generate-and-debug paradigm, combining both qualitative and quantitative information. The design space is explored by first constructing a circuit that produces the desired behavior at the qualitative level, then shifting to the quantitative level to satisfy the design's performance requirements. It will thus provide the ability to generate novel circuit topologies where needed, in addition to using the traditional library-based approach.

Raúl Valdés-Pérez is working on an experimental expert system for schematic generation, assembling a knowledge base of drafting techniques employed by experienced draftsmen, and determining the appropriate computational techniques for putting that knowledge to work. The project is attempting a novel approach to a design task that has to date been automated only by traditional algorithmic means. The result is a program that does placement and, although employing a non rule-based architecture, maintains a distinction between knowledge and inference.

Three other projects form a second component of Professor Davis' expert-systems work. First, Reid G. Simmons is working on a system to do geologic interpretation. This effort focuses on developing a program that understands and is capable of reasoning qualitatively about geologic processes responsible for formations and deposits. This capability is combined with a traditional rule-based expert system to provide a more robust system than is achievable with the expert system alone. The combined system uses the rule-based system most of the time for efficiency reasons, but can fall back on the geologic reasoning system for help in novel situations.

Second, Daniel Weld developed a program capable of unifying discrete and continuous process models of change. Traditionally, two notions of process have been used in programs that reason about change: discrete models, which represent changes as instantaneous, and continuous models, which represent changes as processes that act gradually over time. Mr. Weld's system, called PEPTIDE, uses a technique called aggregation to unify the two types of models, allowing both to be used when performing qualitative simulation, thereby allowing a simulator to switch back and forth between different types of models depending on which is most expedient.

Third, Mr. Jeffrey Van Baalen is working on the challenging problem of selecting representations; attempting to understand what we mean when we call something a good representation. The work currently proceeds by studying in detail the kinds of representations used in several verbal reasoning problems. Of particular interest is the evolution of representations employed in the course of trying to solve a problem, because every representation discarded has a specific shortcoming which each new variant is designed to correct. The ultimate goal of this work is a set of design principles that would permit the analysis of a problem, followed by the selection (and perhaps creation) of a representation well suited to it.

### PROGRAMMER'S APPRENTICE

Dr. Rich and Dr. Waters are developing a theory of how expert programmers analyze, synthesize, modify, explain, specify, verify, and document programs. The long-term goal of such research is to automate the programming process. To achieve this goal, several fundamental problems in Artificial Intelligence must be solved, in particular in the areas of reasoning and problem solving. Dr. Rich and Dr. Waters attack these problems in a more restricted context first, by developing an intelligent computer assistant, called the Programmer's Apprentice. The Programmer's Apprentice acts as an expert programmer's junior partner and critic, keeping track of details and assisting with the routine aspects of the programming process, while allowing the programmer to concentrate on the more difficult parts.

One basic problem currently investigated by Dr. Rich and Dr. Yishai Feldman concerns reasoning with simplifying assumptions. Simplifying assumptions are a powerful technique for dealing with complexity; they are used in all branches of science and engineering. Dr. Rich and Dr. Feldman developed a formal account of this technique in the context of heuristic search and automated reasoning. They have also developed a methodology for choosing appropriate simplifying assumptions in specific domains. This methodology is applied in the Programmer's Apprentice for reasoning about typed partial functions.

Dr. Waters has developed a new technique for automated program translation, called *abstraction and reimplementat*ion. The key to this approach is to analyze automatically the source program in order to obtain an abstract understanding of the computation performed by the program as a whole. Abstraction allows the translating system to grasp the global features of the source program without being distracted by irrelevant details. Using this abstract understanding, the system can then reliably reimplement the source program in the target language.

Dr. Rich and Dr. Waters have also completed editing *Readings in Artificial Intelligence and Software Engineering* (Morgan Kaufman, Los Altos, CA, 1986); a collection of 34 archival papers in the area in the intersection of artificial intelligence and software engineering, including automatic programming, theorem-proving approaches, transformational approaches, specification techniques, intelligent assistants, knowledge representation, and artificial intelligence programming.

## INTELLIGENT SUPERCOMPUTING

### Message-Passing Semantics

The Message-Passing Semantics Group, under the direction of Professor Hewitt, is developing the foundations for large-scale parallel systems that perform robustly in changing environments. Such systems are composed of autonomous computational agents, called Actors, which communicate by passing messages. As a group they have conflicting goals and an incomplete, inconsistent representation of the world. They comprise an open system because they continually change: some change coming from within, through message-passing between internal agents, some from without through interaction with the outside world. Professor Hewitt's actor model provides a suitable basis for developing this concept of an open system because it supports dynamic reconfigurability, compositionality, and extensibility. The group's research focuses on theoretical, architectural, and linguistic aspects of actor systems.

Professor Hewitt and Dr. Gul Agha developed an abstract model for Actors to support open systems. Dr. Agha has also provided a semantics for Actor languages that leads to a better understanding of concurrent systems in their full generality.

Carl R. Manning is working on the implementation of computer languages based on the Actor model of computation and the design of multiprocessor architectures to run these languages. Over the last year he designed a new primitive Actor language based on Dr. Agha's theoretical work and implemented an assembler for this language and a machine simulator that performs Actor programs written in this language. He has been investigating techniques for keeping track of references to Actors so they can be migrated and garbage collected in a tightly coupled network of machines such as the Intel cube. He is working on a compiler for the core constructs of a higher-level Actor language and plans to investigate implementing his simulator on the Intel cube.

Thomas J. Reinhardt worked with Mr. Manning and Dr. Agha on the design and implementation of a compiler for the higher-level Actor language which provides a small and extensible, yet expressive, substrate upon which further experimentation in the development of higher-level languages and AI applications can be constructed.

S. Peter de Jong pursued research concerned with the compilation of high-level programming languages into Actors. Actors are the basic executional element of the Apiary parallel computational facility. Actors communicate via asynchronous messages. The compiler converts synchronous message sending such as occurs in subroutine calls into asynchronous communications by compiling the subroutine call into a leading Actor and a customer. A customer is similar to a continuation, in that a customer contains the script to receive a reply message for a subroutine and to continue processing. Several novel compilation techniques were developed in optimizing the translation: customer sharing minimizes the number of customers generated, parallel unrecursing reduces the number of customer scripts generated, message sharing assures that only one customer script will be generated for each nest of If statements, and customer lifting reduces the number of messages which need to be sent. Mr. de Jong began the investigation of a second line of research concerning the development of a theory of conceptual and organizational development which he is actively pursuing.

### MUSIC COGNITION

Professor Minsky's Music Cognition Group investigates the cognitive foundations of musical behavior. Their objective is to extract and represent expert knowledge about music by building computational models of the cognitive processes involved in composing, performing, and listening.

John Amuedo continued work on a system that generates musical compositions from compact symbolic descriptions. The goal of this work is to develop a composer's apprentice workstation that understands the organization of a set of model pieces well enough to write convincing examples in the same style.

Mr. Amuedo continues to direct a joint research project with the Bösendorfer Piano firm of Vienna, Austria, aimed at producing a concert-quality Recording Piano that exploits personal computer technology. The Laboratory received a production prototype of the Bösendorfer instrument this year, and work has begun on a graphical editor that allows musicians to examine, correct, and extend musical performances by annotating a computer-generated score.

PATRICK H. WINSTON

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## Biotechnology Process Engineering Center

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The Biotechnology Process Engineering Center (BPEC), established at MIT on May 1, 1985, through the National Science Foundation, has made significant progress during its first year. The BPEC administrative offices are now centrally located in Building 20A. Renovation of 7,500 ft<sup>2</sup> of laboratory space to provide centralization of research activities in one building has been initiated. Completion of a 2,300 ft<sup>2</sup> central tissue culture facility to accommodate MIT researchers and visiting scientists is expected in October of 1986.

Twenty-six research projects, involving 18 faculty members from the Departments of Chemical Engineering, Biology, Applied Biological Sciences, Electrical Engineering and Computer Science, and Nuclear Engineering, were established under four research thrust areas:

- Genetics and Molecular Biology
- Bioreactor Design and Operation
- Downstream Processing
- Biochemical Process Systems' Engineering

Two new courses, taught by BPEC faculty, are now offered to MIT students. These are:

- 10.57J )  
20.802J) Modeling of Biological Systems
- 10.56J )  
20.803J) Biotechnology of Mammalian Cells  
7.52 )

Through the Undergraduate Research Opportunities Program (UROP) at MIT, the BPEC extended research opportunities in biotechnology to the entire undergraduate community. Thirty-seven UROP positions, 28 for pay and nine for academic credit, were supported. In addition, 37 graduate research assistants, nine post-doctoral research associates, and 12 research and support staff from the five departments are associated with the activities of this Center.

Avenues for information exchange and mutual support between the BPEC and the industrial community are actively being established. Three biotechnology-related "short courses" were presented at MIT to industrial attendees during the summer of 1985. A total of 250 representatives from industry attended these short courses and six BPEC faculty members participated as directors and/or lecturers.

The first BPEC Symposium, held at MIT in October of 1985, proved to be a very successful forum for information exchange. Over 400 representatives from the chemical, pharmaceutical, and biotechnology industries, as well as 100 people from government and academia, attended this Symposium.

In order for the BPEC to fulfill its commitment to maintaining an active and cooperative interface with industry, the Biotechnology Process Engineering Center Consortium was established. Twenty-seven companies have joined and 10 additional companies have expressed a positive interest in joining. The faculty, students, and staff of the BPEC interact with Consortium members in a number of ways, including special symposia, industrial lectureships, joint research projects, sabbatical exchange programs, personnel recruitment for industry, etc.

The first BPEC Mini-Symposium/Workshop for Consortium members, entitled "Animal Cells: Science and Technology", was held June 4-5 at MIT. Twenty Consortium member companies sent a total of 28 people to the Symposium/Workshop, which included presentation of current research by BPEC faculty members and lively discussion and information exchange amongst the attendees and the BPEC faculty. The next Mini-Symposium/Workshop, entitled "Downstream Processing", will be held July 14-15, 1986.

DANIEL I. C. WANG

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## Center for Advanced Engineering Study

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The rapid pace of technological advance and accelerated international competition have increased general interest in continuing education for engineers in four different ways:

- . The Advanced Study Program allows engineers in professional practice, teaching or technical management to come to the Center for a semester or a year of individual study or for special programs.
- . The Video Course Program provides total quality video-based continuing education to the maximum number of engineering professionals. Currently, more than 1000 videotapes in 50 courses teach over 30,000 engineers, scientists, and industrial managers learning at a distance.
- . The Conference and Seminar Program develops short courses, workshops, and seminars for practicing engineers to study subjects intensively for short periods of time.
- . Through integrated offerings of the Center in which all three portions of the Center participate by focusing their efforts on a particular problem of interest to industry.

### Advanced Study Program

This is an on-campus program that enables engineers and scientists to work in depth in technological areas of their choice. The program serves technical managers who wish to understand developments that bear directly on their problems, men and women who seek competence in depth at technological frontiers, and those who desire to strengthen their technological base. This year there were 61 Fellows from 14 countries. Forty-eight percent of the participants were from the United States.

Fellows of the program are affiliated with the Center for one or more terms. They may develop courses of study to meet their individual needs or may participate in specialized programs. Included in the Advanced Study Program are several specialized programs such as Air Transportation, Systems Reliability and Risk Analysis, Quality and Productivity, Biotechnology, Communications Technology and Policy, and Design and Manufacturing Automation and Control, as well as the Visiting Engineer Program. The Visiting Engineer Program is similar to the Advanced Study Program except that the emphasis is on participation as colleagues in research with faculty members.

The programs coincide with the normal academic terms and year. Special weekly seminars are planned and conducted during the fall and spring terms especially for Fellows of the Advanced Study Program and participants in the Visiting Engineer Program. Each term several special subjects of broad interdisciplinary interest are also offered within the Center for participants in the programs.

Grades are recorded for all MIT subjects taken for credit. A certificate is awarded following satisfactory completion of a program. Fellows also may apply for admission to the MIT Graduate School. The Advanced Study Program is directed by Dr. Paul Brown.

### Video Course Program

The Video Course Program produced several new programs in Fiscal 1986 and has more in development. Among those produced or in development are: Finite Element Procedures for Solids and Structures - Nonlinear Analysis, Advanced Composites, Signals and Systems, Complex Electronics Systems for Production, and Manufacturing in the 1990's (ILP symposium). The Program publishes support print materials for each course in the form of a Video Course Manual, Study Guide, or Visuals Guide. Most courses include problem/solution sets and a hard-cover textbook as part of the comprehensive learning package.

The Video Course Program has taken on two new initiatives to further expand and strengthen the educational outreach of MIT. The goal of both efforts is to transfer state-of-the-art MIT technology to industry expeditiously. First, the Program has expanded into candid-classroom video course development and has assumed the production and distribution of the EECS Lifelong Learning Cooperative Education Program videotapes. Plans are in place to develop candid-classroom video courses in other departments in the Institute. The second new initiative is taping on-campus symposia or conferences sponsored by the Industrial Liaison Program, other centers and labs, plus the Center's own Seminar office. The ILP Symposium on Manufacturing in the 1990's will be published in September 1986 and others are planned for production in later 1986 and early 1987.

The staff of MIT Video Courses manages all aspects of research, concept development, videotape and book production, plus client support. Client support expanded significantly in Fiscal 1986 to include education of course administrators in the use and benefits of VCR-based learning in the workplace. Course administrator's manuals were published that included learning objectives and recommended viewing techniques. The on-going dialogue with client organizations has been carefully documented and is referred to often during the new course development process.

We continue to meet with Department Heads and faculty to determine topics for new course development. Also, surveys are sent to client organizations in order to determine individual client's needs and industrial trends. Course development proposals benefit from the review and consideration of the Video Publishing Advisory Committee, comprised of faculty members from each department. Over one hundred new videotapes will be developed during Fiscal 1987. The Video Course Program is under the direction of Richard J. Noyes.

#### Conference and Seminars Program

The Conference and Seminar Program was established in 1977 to provide professional marketing and logistical support for the growing number of technical continuing education conferences, seminars, and noncredit short courses at MIT. While the majority of programs offered through the Seminar Program originate in the School of Engineering, the Seminar Program is prepared to handle continuing education from any area of science and technology and is designed to manage these programs on and off campus--in the United States and throughout the world. The Seminar Program has received the approval of both the Engineering Council and the Academic Council as a recognized program of continuing education at MIT.

The Conference and Seminar Program manages every aspect of the meeting from concept through post-meeting evaluation. This includes program development, marketing, logistics, and financial management. This professional attention has resulted in a yearly increase in programs. People from more than 49 states and 36 countries have participated in the continuing education offerings from the Seminar Program.

The heavy demand for continuing education offerings has resulted in a growing number of programs at MIT. Some of the 1985-86 programs included: "Artificial Intelligence: Current Applications, Trends and Future Opportunities" sponsored with the Artificial Intelligence Laboratory and Electrical Engineering and Computer Science; "Nuclear Power Plant Innovation" and "Fundamentals of Remote Sensing" sponsored with the Department of Nuclear Engineering; "Advances in Finite Element Methods in Structural Mechanics" with the Department of Mechanical Engineering; "First International Symposium on Innovative Mining Systems: sponsored by the Department of Mechanical Engineering and "Managing Systems of People and Machines for Quality and Productivity" sponsored by the Center for Advanced Engineering Study. The Conference and Seminars Program is directed by Christine Simonsen.

MYRON TRIBUS



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## Center for Technology, Policy, and Industrial Development

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The Center for Technology, Policy, and Industrial Development (CTPID) was established at MIT this past year to focus on policy issues related to science and technology. Creation of CTPID was recommended by an Institute Committee appointed by the Provost, to evaluate MIT activities in technology, policy, and society. The Committee, chaired by John D.C. Little of the Sloan School of Management, concluded "We strongly and unanimously believe that public policy research and education are appropriate at MIT and should be encouraged. We live in a complex society in which science and technology are continuously introducing change. The change creates a stream of public policy issues, whose proper resolution requires technological expertise, understanding of the policy-making process, and analytical skill. MIT, which has always been interactive with society and responsive to national and international needs, can and should play a leadership role in public policy research." The Little Committee recommended that "A new MIT wide centerpiece for policy teaching and research related to engineering and science should be formed within the School of Engineering." The Provost and Dean of Engineering implemented the Little Committee recommendation, and, on June 1, 1985 CTPID was established. CTPID absorbed several ongoing activities including the Technology and Policy Program (TPP) and the Center for Policy Alternatives (CPA).

The new Center builds upon the unique mix of resources at MIT in science, engineering, the social sciences, and management to address complex policy issues with technological or scientific components. CTPID is concerned with public policies, private sector initiatives, and the changing relationship between the public and private sectors in technology related development. In general, CTPID seeks to understand:

- the interface of technology, policy, and society by examining how technology affects society, and the role of public policy in designing and utilizing technology in a responsible manner
- the forces behind technological development from both the public and private perspectives by examining issues such as capital formation, trade and regulatory policies, research and development policy, human resource needs, technological innovation and technology transfer
- the harmful side effects of technology by addressing such issues as the prevention and clearing of hazardous wastes, occupational disease and injury, labor displacement by automation and problems resulting from acid rain.

CTPID is concerned with the development and application of new quantitative and qualitative approaches to technology and policy issues.

A research objective is to improve the overall policy making process where technical judgements are an important component. The current system often generates divisive adversarial debates, delays, and inaction. CTPID seeks to develop a technically sound and less adversarial decision-making process utilizing techniques such as risk assessment, risk management and negotiation techniques.

MIT's most important contributions lie in the objective analysis of policy options rather than pleading for particular policies. Therefore, the Center will evaluate a range of policy options rather than advocate any single approach. CTPID works closely with leaders of government, industry, and labor in a neutral catalytic manner, so they can better understand the implications of technology policy. Center projects often go beyond basic research, and involve implementation activities of an innovative nature to demonstrate how technology and policy interface can be effectively achieved.

A Center Faculty Advisory Program has been formed to set the overall policy of the new Center. Members of the Committee include: Professors Joel Clark, (Materials Science & Engineering), Richard de Neufville, (Civil Engineering), James Fay, (Mechanical Engineering), Jeff Harris, (Economics), Robert Kennedy, (Electrical Engineering and Computer Science), Richard Lester, (Nuclear Engineering), John Little, (Sloan School of Management), David Marks, (Civil Engineering), Ernest Moniz, (Physics), Harvey Sapolsky, (Political Science), Adel Sarofim, (Chemical Engineering), Lawrence Susskind, (Urban Studies & Planning), and Gerald Wogan, (Applied Biological Sciences).

## EDUCATION

The Technology and Policy Program (TPP) educates men and women for leadership on the technological issues confronting society. The main degree offered by the Program is the Master of Science in Technology and Policy. With this diploma graduates can enter directly into practice in government and industry. The Program also sponsors individual, interdepartmental doctoral programs. These are designed for each student according to his or her particular interests. About a fifth of the graduates choose to proceed to doctoral studies, and many do this at MIT.

TPP has grown over the past 10 years with respect to quality and quantity. There are now over 60 masters students in the Program with a strong contingent of women and minorities (20 percent). The quality of the students is reflected in the number and range of fellowships they receive from outside sources. Thus, among current students:

- Seth Tuler was awarded the 1986 Alumni Prize for Excellence and Leadership in Technology and Policy. He also received the William L. Steward, Jr. Award from MIT for his leadership in Student Pugwash.
- Claire Bishoff and Matthew Buresch shared the 1986 Prize for Best Thesis in Technology and Policy.
- Kevin Porter was granted the Alfred Keil Fellowship for the Wiser Use of Science and Technology.

The Program was fortunate to attract support this year from a broad base of corporate, foundation and individual sponsors. Specifically new funding received in 1985-86 includes:

- A grant from the Jessie Smith Noyes Foundation, for the transfer of advanced planning methods to the water utilities.
- A Thesis Fellowship from the Champion International Foundation, for work on environmental policy.
- Funding from Mr. Bernard Rabinowitz, President of Atlantic Industries, to establish the Bernard Rabinowitz Fellowships in Technology and Policy.
- A grant of stock from Mr. Donald Cooke, Chairman of Geographic Data Technology
- A bequest for work on peace and disarmament policy.
- A gift of a microcomputer from ATT, which is being used for work on decision analysis and strategic planning.
- Numerous anonymous gifts from graduates of the Program and other MIT alumni, to provide fellowship support for students in the Program.

## RESEARCH

The International Motor Vehicle Program was started in 1980 to assess the major policy choices facing the auto-producing world. A multimillion dollar program coordinated by MIT, and supervised by Professor Daniel Roos, it is a collaboration of government, industry, and academe to gain a better understanding on an important world industry. A network of researchers from the seven dominant auto-producing countries, and from countries which have growing motor vehicle industries, addresses such issues as international competition in the industry; the changing structure, organization and relationships between motor vehicle producers and assemblers; the advancement of the motor vehicle industry in developing countries; and the effect of computer-aided design, manufacturing and engineering on the industry. Interim research findings are presented for discussion and criticism at annual policy forums attended by leaders in industry, labor, and government. Final results will be reported at international conferences at the end of the study.

The Communications Policy Program - The Research Program on Communications Policy and the Communications Forum are sister programs within the Center. The primary emphasis of the Forum supervised by Professor Robert Kennedy is the coordination of interdisciplinary faculty research. To this end the Forum has primary responsibility for a series of weekly research seminars which combine participation of MIT faculty with other experts from industry and government. The two primary foci of the Research Program's activities are a series of coordinated research studies on the impacts of communications and information technologies and an interdisciplinary graduate educational program in communications. Professor Russell Neuman is the supervisor of the Research Program.

The goal of the Program is to maintain a critical mass of high quality education and research, to offer interdisciplinary training to some of the best young talent in the field, to add a voice of independent and academically based scholarship to the public debate about issues of public communications, and to provide a forum for the public discussion and analysis of communications issues. There are currently seven faculty, 10 visiting scholars and research associates, 14 undergraduates and 27 graduate students associated with the Program.

The Program conducts several research projects including a two-year grant from the Markle Foundation to carry out a program of research on future developments in American telecommunications and a study for the National Science Foundation in the areas of communications standards, information technology and industrial efficiency. Ten undergraduates, six graduate students and two post docs are working at the Audience Research Facility under the supervision of Professor Russell Neuman. Current projects include work on alternative measurement techniques for assessing how people respond to media technologies and tradeoffs among them, the role of audio in the perception of television, political learning from broadcast news, interactive media and High Definition Television. These research projects are helping to develop new forms of data and new analytic tools to assist decisionmakers in reshaping the network structure.

International Competition - Since World War II and until recently the U.S. was supreme in technological development. American economic and technological dominance however has declined just as the world economy has become more tightly integrated. That decline and the shift of basic and new industries offshore is a matter of critical concern to this country, since technological leadership has been a key factor in economic development. Initially, the competition came from Japan, but now other countries in the Far East such as Korea, Taiwan, Hong Kong and Singapore, are emerging as technological competitors to the U.S.

The transfer of technology in mature industries to other countries has been viewed as desirable. However, the degree, scope and intensity of current and foreseeable shifts could pose an economic and strategic threat to the United States. A high priority of the Center is to understand the forces that influence technological development in an era of international competition, to determine what an appropriate and feasible balance is for the United States in technological leadership and to suggest mechanisms from national, state and industry perspectives for the U.S. to achieve its technological potential. In particular, CTPID seeks:

- to raise the level of national concern regarding the seriousness of that decline and its implications on the economic vitality of the country
- to determine what are reasonable and achievable expectations for U.S. technological leadership recognizing that international competition is fundamentally healthy and that transfer of technology to other less developed countries is desirable
- to understand what policies are necessary to foster, develop and deploy technology that enables the U.S. to regain an appropriate technological position in the international community.

Risk Assessment - During the past year the Center has continued to improve the state of the art of quantitative risk assessment for chemical health hazards. The primary thrust of this work, supervised by Dr. Dale Hattis, is to incorporate more information on biological mechanisms into the mathematical formulas used to estimate health risks. There were four significant projects in this area:

- The Magnitude and Implications of Human Interindividual Variability for Risk Assessment. Human data on a number of physiological and metabolic parameters have been analysed to begin to build a quantitative description of variability in key parameters that determine both classical (threshold-type) toxic responses and carcinogenesis in people. This work is supported by the U.S. Environmental Protection Agency's (EPA) Office of Research and Development.
- Incorporation of Pharmacokinetic and Other Mechanism-Related Information into Risk Assessment Procedures for Carcinogens. A pharmacokinetic modelling system is being developed to aid in a comparative series of risk assessments for two-carbon alkylating agents (vinyl chloride, ethylene oxide, ethylene dibromide, ethylene dichloride, perchloroethylene, etc.). This work is sponsored by the National Institute for Occupational Safety and Health (NIOSH) and the National Institute for Environmental Health Sciences (NIEHS).
- Risk Assessment Methodology for Reproductive Hazards-Dynamic modelling approaches are also being applied to teratogenic effects. A case study is being done of a relatively well characterized system -- the production of cleft palates by corticosteroids. This work is sponsored by NIEHS.
- Assessing the Effects of Acid Particulates in the Lung. A model was developed of the action of acid particles of various sizes on the tracheobronchial region of the lung, incorporating particle deposition patterns, the neutralizing capacity of lung mucus, and the changes in local pH that seem to be required to produce detectable responses. This work is sponsored by the Department of National Health and Welfare, Canada.

The Center is planning a meeting in the Fall at Endicott House to discuss MIT's future directions for study of risk assessment and risk management issues.

Biotechnology - The commercial development of biotechnological products is only in its early stages, and government is likewise in the early stages of developing policies to apply to those products. Researchers at MIT are leaders not only in the development of these technologies, but also in the evaluation of their social, political, and economic implications. Their research includes the development and analysis of policy options for regulating biotechnology and for evaluating the likely effect of such regulation on health and environmental risks, international trade, patents, and innovation. Research is also underway on biotechnology applications that may require additional investment from public sector sources, such as vaccines for third world disease.

Technology and Law - The Center is involved in a number of research projects involving technology and law. These projects supervised by Professor Nicholas Ashford include:

- A study on the development of labor law in the area of technology bargaining which traces the evolution of management's obligations to bargain with labor over the introduction of technological change. The next phase of the research will be an in-depth study of actual activities in labor management cooperation concerning the adoption of new technology.
- A multi-media approach involving the control of toxic substances through the encouragement of technological innovation is the subject of research currently being undertaken. The use of regulation to stimulate technological change in combination with economic incentives represents the focus of the research.
- Monitoring communities for exposure to toxic substances in the environment raises scientific, legal, and ethical issues. The decision and conduct of human monitoring is a subject of current research initiatives.
- An examination of insurance liability related to the production and disposal of chemicals. Recommendations for insurance and tort law reform will emerge from the research.

Hazardous Wastes - Hazardous waste is defined loosely by the EPA as toxic, corrosive, flammable or explosive materials. The management of these substances is a complex problem that is only beginning to be understood. Nonetheless the implications for public health and for our technologic development of these "side effects" will be a central issue for our society in the decades to come. CTPID has formed an MIT interdisciplinary initiative in hazardous waste management. Professor David H. Marks, Head of the Department of Civil Engineering, organized a one day discussion at Endicott House in January 1986 to help understand the sorts of issues that MIT might focus on in research and educational programs that would go beyond traditional disciplinary activities in hazardous waste management. Seven areas were covered at the session:

- Mediation of Science Intensive Disputes - Professsor Larry Susskind, Department of Urban Planning
- Estimating the Health Effects of Hazardous Materials - Professor Gerald Wogan, Department of Applied Biological Sciences
- Process Change to Prevent the Production of Hazardous Wastes - Professor Lawrence Evans, Department of Chemical Engineering
- The Key to Future Waste Management is Through Process Change Management of Businesses after RCRA and CERCLA - Professor Gordon Bloom, Lecturer, Sloan School of Management
- Prospects for Safe Incineration of Hazardous Materials - Professor Adel Sarofim, Department of Chemical Engineering
- Hazardous Wastes and Ground Water Pollution - Professor Lynn Gelhar, Department of Civil Engineering
- Metals, Radionuclides, Organic Compounds: Research on Processes Controlling Their Fate on the Aquatic Environment - Professor Philip Gschwend, Department of Civil Engineering

Out of this meeting (proceedings are available upon request from CTPID) a working faculty group has been formed focusing on research and education issues. A spring seminar series was conducted to better define potential research activities and a new MIT research program in hazardous waste management has been defined. That Program will combine public and private sector funding and focus on both basic and applied research. The initial area of concentration for applied research will be household hazardous waste. Households take in hundreds of products that contain toxic substances. These include pesticides, paint products, household cleaners, and automotive products. However, very little is known about the quantities of materials involved, or the health effects from exposure to these substances. So little is known about these household problems that a first look at exposures and human response is essential followed by the development of innovative technologies and policies that can be implemented to address the problem.

DANIEL ROOS

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## Center for Transportation Studies

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### Introduction

The Center for Transportation Studies was founded in 1973 to stimulate and coordinate transportation research and education at MIT, and to develop working relationships with the transportation profession. Since its beginning, the Center has conducted nearly \$17 million of research involving all transportation modes in both the public and private sectors. The Master of Science in Transportation (MST) Program has graduated 94 students since 1979, and they are highly sought after in the job market. The Transportation Computing Lab has been expanded. Our continuing education programs bring many professionals to MIT every year. Our Affiliates Program continues to expand. Further, our Forum program for leaders in the transportation field from industry and government has been a continuing success.

### Change of Leadership

Professor Daniel Roos stepped aside as Director of CTS to become the first Director of MIT's newly-formed teaching and research Center for Technology, Policy and Industrial Development. The appointment was a natural outgrowth of his leading role in major research efforts in technology and policy, including his co-direction of the International Automobile Program. Professor Roos will remain closely allied with the Center for Transportation Studies. The affiliated faculty and staff of CTS wishes to thank Professor Roos for seven years of strong and effective leadership.

Professor Joseph Sussman, most recently Head of the Department of Civil Engineering was named as new Director of CTS during this year. Gerard McCullough, who served as acting director for part of the year, continues in his role as Deputy Director of the Center.

### Executive Committee

The Center has working relationships with over 60 faculty members from ten departments at MIT. Direction is provided by the Executive Committee, made up of faculty representatives, which included the following members in 1985/86: Professor Ralph Gakenheimer (Department of Urban Studies & Planning), Professor Jerry Hausman (Department of Economics), Professor Thomas Magnanti (Head, Management Sciences Area, Sloan School of Management), Professor David Marks (Head, Department of Civil Engineering), Gerard McCullough (Deputy Director of the Center), Professor Francis Ogilvie (Head, Department of Ocean Engineering), Professor Joseph Sussman (Director of the Center), Professor Yosef Sheffi (Head, Transportation Systems Division, Department of Civil Engineering), Professor Robert Simpson (Head, Flight Transportation Laboratory, Department of Aeronautics and Astronautics), and Professor David Wormley (Head, Department of Mechanical Engineering).

### Research

The research program of the Center continues as a broad based set of activities involving faculty and students from a number of different departments. Of special note are the following initiatives:

- The Center developed an expanded research program with the Transportation Systems Center (TSC) of the United States Department of Transportation. Research in air transportation, rail passenger demand, bridge maintenance, technological issues in rail infrastructure and rolling stock, and urban bus systems were undertaken by affiliated faculty and staff through TSC research support.
- The Center developed several major programs with state government in New England. With the Massachusetts Department of Public Works (MDPW), CTS faculty staff began programs in: 1) Development of Transportation Strategies in High Growth Corridors 2) Highway Maintenance Management 3) Applications of Computers to Problem Solving (several short subjects given to MDPW staff were a component of this program) 4) Impact of the Seat Belt Law and 5) Estimation of Intersection Safety.

Also, the New England Transportation Infrastructure Consortium continued to be a major initiative of the Center (in cooperation with the Center for Construction Research and Education). This consortium involves MIT, the Universities of Vermont, New Hampshire, Maine, Rhode Island, Massachusetts, and the State transportation agency in each of these five states. Preliminary research on concrete bridge deck deterioration and the over-size, overweight truck permitting process was performed this past year with an expanded program in these two areas and others anticipated for next year.

- The Center continued to develop the area of logistics in projects with 1) The Grand Truck Western Railroad in the area of locomotive fleet management 2) North American Van Lines in the area of truck routing and scheduling 3) IU International on large scale network optimization 4) United Parcel Service (UPS) on extended analysis methods for metro planning and 5) the Office of Naval Research on sealift routing and scheduling.
- Through its designation as an AAR Affiliated Lab, CTS worked on a number of rail related research projects including railroad productivity, energy consumption due to vehicle/track dynamics, rail maintenance management, single axle freight trucks, and robotics in railroad shops.

#### CTS Affiliates Program

The Affiliates Program is an important element in the educational and research programs of the Center. It also adds a public service dimension to transportation activities at MIT.

The Affiliates Program was established in 1981 with the aim of encouraging contacts between MIT faculty and organizations involved in private sector transportation. Membership in the Affiliates now comprises 14 firms and includes the country's strongest shippers and carriers. Members include Digital Equipment Corporation, General Mills, General Motors, Gillette, IBM, IU International, 3M, North American Van Lines, Ryder, Seaboard System Railroad, Sea-Land, and Southern Pacific, with Burlington Northern and Rockwell joining the program in this past year. Bayer A.G. and Dupont are scheduled to join next year. Much of the growth in the program has come from shipper organizations eager to use computer-based planning techniques and innovative technology to take advantage of a new transportation environment created by deregulation.

Educational activities of the Affiliates Program include several technical seminars a year which focus on topics of mutual interest to Affiliate staff and MIT faculty members. Topics covered this year have included financial analysis of motor carriers and technological and economic trends in ocean freight shipping. In the summer CTS conducts a very successful Executive Program in Transportation devoted to developing a common set of analytic techniques to be used by carriers and shippers in the new freight markets. The Affiliates Program also has played a role in student education by providing summer employment (and long term employment) opportunities for MIT transportation students. This program will be formalized this year as the CTS Affiliates Internship Program.

Each year one of the Affiliate firms sponsors the annual Affiliate Meeting at a working site which combines logistics demonstrations with lectures by MIT staff and Affiliate staff. The host for the 1986 meeting was UPS. Next year, the host will be 3M.

#### CTS Forum

The CTS Affiliates Program has given faculty and research staff access to transportation decision makers at the highest levels. It also has given these decision-makers an opportunity to meet with MIT researchers and to work with each other at a time when transportation markets are changing dramatically. This mutual interaction has given MIT an opportunity to provide a significant public service by helping to shape an agenda of issues for transportation decision-makers in the coming decade. This agenda-shaping process was formalized last year with the inauguration of the CTS Forum series at MIT Endicott House in June 1985.

The format of these meetings is straightforward. Thirty decision-makers, usually the CEO's of carriers and the VP's for logistics of shippers, are invited to spend two days with MIT faculty and top government officials discussing transportation issues. The issues are a) changing relations between carriers and customers b) changing labor and management responsibilities, and c) changing public and private responsibilities. The groups devote a half day to each of these topics.

A west coast forum was held in January 1986 and a third forum will be conducted at Endicott House on September 5-6, 1986.

Participants have been drawn from the top ranks of companies that provide and use transportation services, as well as government and academia. Attendees have included Joseph Abely, Jr., Chairman of Sea-Land Corporation; the Honorable James Burnley, Deputy Secretary of Transportation; Darius Gaskins, President, Burlington Northern Railroad; Kenneth W. Maxfield, President, North American Van Lines; Professor Paul Samuelson of MIT, Nobel Laureate in Economics; Clifford Sayre, Director of Logistics, Du Pont; Denman McNear, Chairman and Chief Executive Officer, Southern Pacific Transportation Company, and others.

#### Education

The Master of Science in Transportation (MST) Programs continues to operate effectively. We have a strong class to be enrolled in September 1986. A good deal of planning and redesign of the two required subjects (CTS 100-Transportation Systems Analysis and CTS 110-Transportation Economics) was undertaken during this year, which will lead to a broader transportation perspective in both subjects. Also, our offerings in the transportation infrastructure area underwent a major review, leading to a more coherent set of subjects. A new subject in Transportation Policy Analysis was offered last fall for the first time.

We are very proud of the positions our MST graduates have attained. They have achieved senior positions with public transportation organizations, major carriers in the various modes, large scale shippers, and in consulting, investment, and engineering organizations.

Summer subjects for professionals in transportation include: 1) Logistics Analysis for Carriers and Shippers 2) Transit Management and 3) Discrete Choice Analysis.

#### Transportation Computing Lab (TCL)

The Center formally established a Transportation Computing Laboratory two years ago to serve as a focal point for academic and research computing activities. Several new initiatives are underway in computing in CTS, made possible by the generous support of the UPS Foundation funded by the United Parcel Service.

The addition of a number of personal computers makes the laboratory an ideal facility for academic use. Most of the subjects in the Master's Program make some use of the personal computer in their curriculum, including the core courses, Transportation Systems Analysis and Transportation Economics.

Two DEC MicroVax minicomputers were acquired. One of the MicroVAX minicomputers is being used as a multi-user system, and will support 16 users, including faculty offices and the Center's headquarters. This machine will be used for academic and research use, with its primary function dedicated to statistical and database applications. The second minicomputer, a MicroVAX Workstation, will be used as a CAD/graphics system, supporting a single user. The workstation will enable students to develop sophisticated models complete with high quality graphics. The primary use of this machine will center on infrastructure and highway applications, and network representation and simulation.

The TCL is used as a resource for summer and special studies courses. Four intensive two-day seminars for staff of the MDPW covered such topics as structural analysis of bridges, highway and earthwork geometry, traffic and intersection analysis, and database management. Several summer studies courses offered by the Center's faculty also make use of the laboratory for demonstrations and hands-on sessions.

Research activity has continued to grow in the TCL. Projects in development of maintenance management tools, transit service reliability and data collection, traffic and signal analysis, and locomotive reliability and assignment were among the projects using the TCL.

#### United Parcel Service (UPS) Fellowships

The Center continued its fellowship program funded by the UPS Foundation. One fellowship is made available to an incoming MST student and one fellowship is awarded to a doctoral candidate to support thesis research. In both instances this year, the award was split between two students. The winners of the MST fellowship were Martin Liss and Reina Rotshild and the doctoral fellowship was shared by Cynthia Barnhart and David Geltner.



### Seminar Series

This year, CTS offered a Seminar Series jointly with the New England Chapter of the Transportation Research Forum. This joint offering helped us attract a broader audience and allowed for better interaction between our students and the local professional committee. We expect to continue in this format in the upcoming year.

JOSEPH M. SUSSMAN

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## Laboratory for Computer Science

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The MIT Laboratory for Computer Science (LCS) is an interdepartmental laboratory whose principal goal is research in computer science and engineering.

Founded in 1963 as Project MAC (for Multiple Access Computer and Machine Aided Cognition), the Laboratory developed the Compatible Time Sharing System (CTSS), one of the first time shared systems in the world, and Multics -- an improved time shared system that introduced several new concepts. These two major developments stimulated research activities in the application of on-line computing to such diverse disciplines as engineering, architecture, mathematics, biology, medicine, library science and management. Since that time, the Laboratory's pursuits expanded, leading to pioneering research in Expert Systems, Computer Networks and Public Cryptography. Today, the Laboratory's research spans a broad front of activities, grouped in four major areas.

The first such area entitled Knowledge Based Systems, involves making programs more intelligent by capturing, representing, and using knowledge which is specific to the problem domain. Examples are the use of expert medical knowledge for assistance in diagnosis carried out by the Clinical Decision Making Group; and the use of solid-state circuit design knowledge for an expert VLSI (very large scale integration) design system by the VLSI Design Project.

Research in the second and largest area entitled Machines, Languages, and Systems strives to discover and understand computing systems at both the hardware and software levels that open new application areas and/or effect sizable improvements in their ease of utilization and cost effectiveness. New research in this area includes the architecture of very large multiprocessor machines (which tackle a single task, e.g., speech understanding or weather analysis) by the Computation Structures, Real Time Systems, Information Mechanics, and Parallel Programming Research Groups. Continuing research includes the analysis and synthesis of languages and operating systems for use in large geographically distributed systems by the Distributed Systems and Programming Methodology Groups. Finally, a key application involving the matching of news and other community information to individual needs, is pursued by the Programming Systems Research Group.

The Laboratory's third principal area of research, entitled Theory, involves exploration and development of theoretical foundations in computer science. For example, the Theory of Computation Group strives to understand ultimate limits in space and time associated with various classes of algorithms; the semantics of programming languages from both analytical and synthetic viewpoints; the logic of programs; the utility of randomness in computation; concurrent computation and the links between mathematics and the privacy/authentication of computer-to-computer messages. Other examples of theoretical work involve the study of distributed systems by the Theory of Distributed Systems Research Group, and the development of effective algorithms for VLSI design.

The fourth area of research entitled Computers and People, is concerned with the interrelationships between people and machines -- for example, the societal impact of computers carried out by the Societal Implications Research Group.

Highlights of the 1985-86 research were as follows:

The Multiprocessor Emulation Facility was rendered operational and was used for its intended purpose of emulating our Laboratory's Tagged Token Dataflow architecture. This facility currently consisting of 38 Lisp Machines which are interconnected by Laboratory designed high speed switches was designed to be a testbed for experimental study of various candidate multiprocessor architectures. The results of these first emulations and related studies have led us to revise our designs for a tagged dataflow machine, which we hope to build within the next three years. A comprehensive software system has also been completed that translates functional programs from the language Id to representations that can be emulated on the above facility, simulated on an IBM 4381 computer, or executed on a dataflow machine.

During this period we have also launched the design of two additional multiprocessor projects: Project L and CAM-7. L is a new model of computation characterized by (1) a large collection of finite state machines and state representations with the property that programs written in object-oriented languages (with concurrency) can be efficiently compiled into L structures; and (2) L structures can be efficiently executed on a proposed hardware architecture associated with the L project.

The CAM-7 architecture is a cellular automata machine that further extends our previous architectures in this area. This machine will be able to update in one screen refresh interval half-a-billion digital cells which are configured either as a cube or as a plane. The state of each such cell is

updated on the basis of the states of its physically adjacent cells, as dictated by a set of rules that apply uniformly to all cells. We use these cellular automata structures for a variety of purposes including the development of simple computational models that explain relatively complex physical phenomena.

In January 1986, we formally launched the LCS Common System research effort. This ambitious project aims to facilitate the composition of programs across different computational environments. For example, a program written in a Lisp machine environment should be able to use a subprogram written in C under a Unix environment. We expect to complete the first definition of this system by year's end, at which point we will begin gradual implementation of the Common System on the Laboratory's 100 Lisp Machines and VAX-2 workstations.

An additional research activity launched in 1985-86 involves learning. This "Artificial Awareness" program, as it is called, strives to develop theories and machines that can learn from their environments (and not from their programmers) certain elementary notions. We believe that technological progress in architectures and VLSI calls for a re-examination of learning theories and learning machine architectures that may perhaps be implemented by "neural" types of machines.

In the theoretical area, Professor Shafi Goldwasser has established important results concerning the speed with which the primality of large integers can be tested.

During 1985-1986, the Laboratory has continued its successful Distinguished Lecturer Series with presentations by Princeton University Professor Robert E. Tarjan; Executive Director of Research at AT & T Bell Laboratories' Communications Sciences Division, Robert W. Lucky; Cornell University Professor John E. Hopcroft; Tufts University Professor of Philosophy Daniel C. Dennett, Chairman of the Board of Microsoft, William H. Gates; and University of Kent at Canterbury Professor David A. Turner.

The Laboratory had several personnel changes over the past year including the addition of Mathematics Department Professors Baruch Awerbuch and David Schmoys, and Dr. Lennie Heath as members of the Theory of Computation Group; the arrival of Drs. Sharon Marshall, Stephen Garland, and Toby Bloom as research associates in the Clinical Decision Making, Systematic Program Development, and Distributed Computer Systems Groups, respectively; the departures of Professor Christopher Terman to Symbolics, Inc., Dr. Andrea diSessa to Berkeley, Research Associate Dr. William Ackerman to Apollo Computer, Research Associate Sylvia Weir to the MIT Arts, Media & Technology Center, and Adjunct Professor Maurice V. Wilkes, who returned to his home in the United Kingdom. Other changes included the appointments of Dr. Tommaso Toffoli to head of the Information Mechanics Group, Dr. Andy Boughton as Research Associate in the LCS Multiprocessor Emulation Facility, and Professor Robert H. Halstead as head of the newly formed Parallel Programming Research Group. Additionally, the Functional Languages and Architectures, and Computation Structures Groups have merged, retaining the name of the latter.

Our Laboratory consisted of 331 members -- 44 faculty, and academic research staff, 30 visitors and visiting faculty, 62 professional and support staff, 105 graduate and 90 undergraduate students -- organized into 15 research groups. Laboratory research during 1985-86 was funded by 12 governmental and industrial organizations, of which the Defense Advanced Research Projects Agency of the Department of Defense provided over half of the total research funds. Also during the same period the Laboratory employed 23 undergraduates through the "Hacker Heaven" project which strives to identify promising potential researchers in Computer Science.

Technical results of our research in 1985-86 were disseminated through publications in the technical literature, through Technical Reports (TR 331-TR 366), and through Technical Memoranda (TM 280-TM 295).

MICHAEL L. DERTOUZOS

The Laboratory for Electromagnetic and Electronic Systems (LEES) is a coalition of 17 faculty and 10 research staff from the departments of Electrical Engineering and Computer Science and Mechanical Engineering. Disciplines represented included power electronics, automatic control, electromechanics, continuum electromechanics, high voltage research, heat transfer, insulation research, quantitative physiology, cell biology and systems analysis and economics. Faculty and students collaborate in projects aimed at both the practical engineering objectives of sponsors and at the underlying engineering sciences. Interactions with other laboratories is encouraged, including the Energy Laboratory Electric Utilities Program.

### CURRENT RESEARCH

#### Power Electronics

Power electronics research is lead by Profs. J.G. Kassakian, M.F. Schlecht and G. C. Verghese. The focus continues to be the technology development for using r.f. switching to create small, component-like power supplies. These micro-supplies are seen as leading the next revolution in power supply architectures for computers. A 4MHz, 90W converter using quasi-resonant switching has been demonstrated. The new power mos field effect transistor with an integral turn-off structure reported last year has been fabricated and tested. Devices suitable for use in prototype converters are now in process. A new transformer structure compatible with the envisioned two-dimensional form of the micro-supply has been created using ferrite sheets and a kapton based flexible circuit.

Under the guidance of Prof. Schlecht, and using the resources of the Microsystems Technology Laboratory, power semiconductor device research continues to grow. In addition to the power mosfet work, he and his students are studying the use of amorphous silicon for power devices.

Prof. Verghese directs research on nonlinear and/or time-varying controllers for power electronic circuits. The research builds on continuous-time and more accurate sampled-data models of power circuit dynamics. Two new microprocessor-based schemes have been designed and are presently being tested. One is a nonlinear controller for stabilizing a switched converter in the face of large perturbations, and the other is a linear time-varying controller for stabilizing a converter in the presence of small perturbations. The use of a microprocessor enables adaptation to varying operating conditions.

The MIT/Industry Power Electronics Collegium continues to be a source of support and guidance for the power electronics activities. A workshop on Computer Aided Engineering for Power Electronics and Electrical Machines was held for Collegium members this spring. Through the development of an MIT graduate subject and a summer course for industry, power electronics research has a strong influence on graduate and continuing education.

#### Systems Identification and Control

Parameter estimation, especially in distributed systems, is an area of continued emphasis. Professor J.H. Lang continues theoretical, numerical and experimental studies of model reference adaptive observers for flexible structure parameter identification. Recently demonstrated is the operation of observers in the face of unanticipated noise and nonlinearities. It is anticipated that the observers will be tested on a large scale flexible structure at the Draper Laboratories during the next year.

By means of theory and numerical and physical experiments, Profs. Lang and G. C. Verghese have shown that state estimators driven by voltage and current measurements from the terminals of an electric machine can be used to estimate rotor position with sufficient accuracy to replace shaft encoders (or support torque control in a wide range of applications) for the purposes of commutation and perhaps for fine position control. One experiment involving a variable reluctance motor has demonstrated the estimation of rotor position to within one part in 50,000 of a revolution. This is near the accuracy desired by many robotics or manufacturing applications. These projects are representative of a new theme emerging in electromechanics, and supported by application of estimation theory and digital electronics, namely the use of electrical machines as sensors as well as actuators. As sensor, these new machine systems will not only improve their control, but also reliability through the support of failure analysis. The study of failure analysis systems for electrical machines is just beginning and proceeds with the hope of predicting failures before they occur.

## Electromechanics, Heat-transfer and Cryogenics

The Integrated Machine is a continuing theme, guided by Profs. Lang, Verghese and R.D. Thornton. The research to design drives for servo-robotics has resulted in a motor having a very high torque to mass ratio, sufficiently high to support the direct drive of robot arms. It is this motor which also supports the high accuracy rotor position estimation, so that the development of integrated actuators and sensor has arrived. This work is expected to result in a commercial product by the end of the year.

With the objective of demonstrating the viability of a new technology for large synchronous generators, Profs. G.L. Wilson, J.L. Smith Jr., J.L. Kirtley, Jr., Dr. S.D. Umans, Mr. D.M. Otten, Mr. G.Y. Robinson and Mr. W.H. Hagman have constructed and are testing a 10 MVA superconducting machine. Improvements to the rotor cooling and thermal isolation system have been made, including additions to the on board data acquisition program permitting instantaneous analyses of the cryogenic performance of the system and modification of the refrigeration equipment to facilitate cool-down operation and to make the machine operable in a power plant environment. Development and redesign of the novel rotating helium seal was completed and the seal tested. Modifications are currently underway of the commercial main shaft seals. This will permit continuous operation of the machine at rated speed without vacuum degradation.

## Continuum Electromechanics

Professor Melcher has identified and developed (in theory) a noninvasive ion-drag velocimeter. Mounted flush with a wall bounding a streaming insulating fluid, it can be used to deduce the velocity profile with respect to the coordinate normal to the wall. This is done with the aid of an algorithm for deconvolving the profile from measurements made from the wall. Experiments are underway to demonstrate the approach.

Stimulated by recently developed integrated interdigital electrode "chips" for dielectrometry (Prof. S. D. Senturia of the Microsystems Technology Lab.), Prof. Melcher and his students have developed a modal approach to describing interactions with heterogeneous media. This work makes microdielectrometry, and general dielectrometry based on the use of periodic structures, applicable to estimating such parameters of heterogeneous systems as film thickness, complex permittivity of layers of finite thickness and the surface conductivity of films. (Without making electrical contact, the chip can now be used to measure surface conductivities as small as  $10^{-18}$  Siemens.) These results are also an important step toward applying this technology to quantitatively investigating the weak diffuse double-layers found in highly insulating liquids as well as electromechanical (flow) and chemical effects. A class of parameter estimation schemes has been demonstrated on the computer to make possible the deconvolution of properties such as complex permittivity from data taken at variable wavelength but at a given frequency. This work underlies a number of avenues for future research, some connected with the transformer project described later.

In a projects concerned with the electrostatic spraying of metallic paints, Prof. Melcher and his students have succeeded in verifying the Bell-Hochberg postulate of (so-called) electrostatic discoloration. It has been shown that, rather than resulting because of field induced flake alignment, the lighter appearance of electrically deposited metallic paints results because of the efficiency with which the painting is accomplished. The mechanical sprayers fail to deposit the small drops which have less than their share of metallic flake, thus giving a relatively greater metallic appearance. Unfortunately, this appearance comes at the price of greater pollution and waste of paint and a new approach to automotive finishing, ranging from color selection to process control, is called for. As a side project, a technique for the electrical production of images in metallic paints has been developed, including an exposition of the effects of paint visco-elastic properties on flake orientation scaling laws.

## High Voltage and Insulation Research

Now in its second year, the Transformer Project is coordinated by Dr. Cooke and is to develop in-service methods for detection of hazardous conditions within large power transformers. Expanding on the semiconductor microchip technology of the first year, guided by Prof. Melcher, a solid-state moisture in oil detector has been developed. A non-destructive dielectric test method to measure the insulating quality of oil based upon nanosecond pulse measurements and proposed scheme to use coincidence gating and time domain filtering for noise suppression in the measurement of partial discharges have also been developed (Dr. Cooke). Methods for vibration monitoring of transformers (Prof. Kirtley) have demonstrated the feasibility of the detection of loose windings. The model used here is based on identified coefficients which relate the time harmonics of the transformer voltage and current to acoustic vibration harmonics of the windings. It has been found to be possible to estimate these parameters and to identify changes in them due to temperature and to moderate "damage" to the winding produced by removing spacer blocks or imposing short-circuit currents. Advanced thermal monitoring

strategies have been developed by Prof. Schweppe and Dr. Tabors. The integration of these and more conventional sensors into a trend analysis system is to be demonstrated during the next year in a pilot facility being coordinated by Mr. Hagman.

In his work with compressed gas insulation, Dr. Cooke has employed the knowledge gained from studies of HVDC power apparatus to design insulators for extending acceleration tubes and supporting voltage grading electrodes in a 35MV French accelerator called Vivitron. A demonstration machine is being built in France.

The availability of energetic electrons at the High Voltage Laboratory has made possible a series of studies. Dr. Cooke, Mr. K.A. Wright and Prof. T. Takada of Japan have extended pulsed-acoustic methods to investigate charge transport in dielectrics to doses comparable to those for medical applications. The acoustic method has shown good agreement with distribution and decay of beam injected charges found in earlier electro-optic charge distribution studies by Dr. Cooke, following self-precipitation rather than ohmic conduction decay. Professor Zahn, in collaboration with Dr. Cooke and Mr. Wright, has used electro-optic methods to see electron beam charging of plexiglas, allowing direct measurement of charge trapping, transport and relaxation with application to the charging of spacecraft.

Professor Zahn has extended his past Kerr electro-optic techniques to field and charge mapping in the low Kerr constant materials of interest in electric power apparatus and pulsed power systems. These materials included transformer oil, PMMA and both liquid and gaseous sulfur hexafluoride. A focus is the role of interfaces, such as between transformer oil impregnated paper and oil, in charge injection processes thought to be factors in flow electrification. Professor Zahn collaborates with Prof. Melcher in the study of streaming currents produced by fluid flow along such interfaces. A model for the influence of charge transport on terminal characteristics has been developed by Zahn and shown to explain experimental data for dc, ac and pulsed systems. It will be used together with a new computer based optical data acquisition and processing system to allow direct interaction between analysis and measurements.

#### Biological Electromechanics and Physiology

Professor Grodzinsky and his group are studying the influence of electromechanical interactions in repair and pathological degeneration processes in cartilage. (This work was recently awarded the Kappa Delta Prize for outstanding research by the Bioelectrical Repair and Growth Society.) They have discovered that mechanical strains generated by applied electric fields in cartilage provide a highly sensitive "molecular electrophoretic" probe for quantifying the mechanism and the kinetics of breakdown of the molecular network of cartilage. Such breakdown may occur in arthritic-like diseases. In addition, the interaction of environmental electromagnetic fields with biological tissues is being studied using the possibility that applied fields may cause cartilage cells to synthesize special "stress response proteins" in living tissue in organ culture. This work resulted in an award to PhD student Ms. Laura MacGinitie by the Bioelectromagnetics Society for the best Student Paper at last year's international conference.

Ongoing research by Prof. Grodzinsky concerning electrical and chemical control of membrane transport focusses on drug delivery and chemical separations. The potential importance of such techniques to protein separations in biotechnology has led to collaborative support in the new Biotechnology Process Engineering Center at MIT. Recent results have shown that modulation of the charge density of synthetic hydrogel membranes by electrical or chemical means can be used to selectively separate two fluorescently tagged solute probes in the same feed solution.

Profs. R. C. Lee and Grodzinsky collaborate on studying the effects of mechanical loading forces on cellular response in cartilage. They have recently found that cell synthesis appears to be controlled in part by compression-induced changes in cartilage's high fixed charge density. This lends insight into the mechanisms of mechanical regulation of skeletal growth. When epiphyseal cartilage is loaded, biosynthesis is depressed, when the load is released, protein synthesis is accelerated to a level above the baseline rate. This suggests that the cells are attempting to change the composition of the cartilage matrix.

In further studies on the mechanism of electric field stimulation of regulation of cellular metabolism, Prof. Lee has found that the field intensity threshold previously reported is dependent on both the frequency of the field and the length of the cell in the direction of the field. Further work related to electrical injury has begun to identify the electrical conditions for field induced rupture of human cells.

In the radiotherapy program, Kenneth Wright continues to collaborate with members of the Lahey Clinic to develop new treatment techniques, including dosimetry evaluation methods, calibration protocols for applying high energy X-ray and electrons and application of data from CT scans to improve treatment planning.

### Power System Integration and Economics

Work on Spot Pricing by Prof. F. C. Schweppe and Dr. R.D. Tabors has led to the draft of a book (with Prof. M. Caramanis (Boston Univ.) and Prof. R. Bohn (Harvard Business School) Electric Utility Spot Pricing. Professor Schweppe, working with Dr. E. J. Kern, has developed a nonintrusive means of measuring appliance electric energy consumption through rapid sampling of household power and energy consumption. This method, called Appliance Signature Identification, will be under hardware testing in 1987.

For the third year, Prof. Schweppe and Dr. Tabors taught a special summer session course "Power System Planning and Operation: Methodologies for Dealing with an Uncertain Future" attended by 25 representatives of regulatory bodies, utilities and large industrial consumers.

JAMES R. MELCHER

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## Laboratory for Information and Decision Systems

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The Laboratory for Information and Decision Systems (LIDS) is an interdepartmental research laboratory of the Massachusetts Institute of Technology. Its staff includes faculty members, full-time research scientists, postdoctoral fellows, graduate research assistants, and support personnel. Undergraduate students participate in the research program of the laboratory through the Undergraduate Research Opportunities Program (UROP). Every year several research scientists from various parts of the world visit the laboratory to participate in its research program.

The fundamental research goal of the laboratory is to advance the field of systems, communication and control. In doing this it explicitly recognizes the interdependence of these fields and the fundamental role that computers and computation play in this research. The laboratory is conducting basic theoretical studies in communication and control and is committed to advancing the state of knowledge of technologically important areas. For example, Flexible Manufacturing Systems is currently an important research area in the laboratory.

As an interdepartmental laboratory, LIDS reports to the Dean of the School of Engineering, Professor Gerald L. Wilson. The Director of the laboratory is Sanjoy K. Mitter, Professor of Electrical Engineering. Robert G. Gallager, Professor of Electrical Engineering, is the Associate Director. The Assistant Director is Stanley B. Geršwin, Principal Research Scientist.

Thirteen faculty members and seven research staff members are presently associated with the laboratory. In addition, approximately sixty graduate students conduct research in LIDS. Currently, the laboratory provides thirty-five research assistantships to graduate students. A number of undergraduate students also participate in research and thesis activities. The laboratory also makes a number of post-doctoral and visiting appointments. This year two internationally renowned engineers, Professor Bruce Hajek (University of Illinois) and Professor Lennart Ljung (Linköping University, Sweden), visited the laboratory.

Financial support for research in the laboratory is provided by Defense Advanced Research Projects Agency, Army Research Office, Office of Naval Research, Air Force Office of Scientific Research, National Aeronautics and Space Administration, National Science Foundation, National Institutes of Health, IBM Corporation, Dupont Corporation, General Electric Company, Data General Corporation, Codex Corporation, Motorola, Inc., and the Analytical Sciences Corporation.

### CURRENT RESEARCH

The current research activities of the laboratory cover a wide range of theoretical and applied areas in systems, communications, and control. These areas include:

#### Data Communication Networks

Research in Communication Science and Systems ranges from basic information theoretical studies of networks and communication channels to the architectural design of network protocols. The major objective of this work is to develop the scientific base needed to design data communication networks that are efficient, robust, and architecturally clean. Both wide area and local area networks and both point-to-point and broadcast communication channels are of concern. Some of the topics in this area are routing, flow control, diverse traffic mixes, the communication complexity and delay of distributed algorithm protocols, multiaccess contention resolution, failure recovery and topological design. Professors Dimitri Bertsekas, Robert Gallager, Pierre Humblet, and Robert Kennedy are conducting this research.

#### Fiber Optic Local Communication Networks

The goal of this newly initiated program is to identify and resolve the fundamental issues pertaining to the design of local communication networks that utilize very broad band optical fiber technology to realize an integrated system that can provide all necessary communication services in a campus environment. Theoretical, experimental and design activities will contribute to the work.

Particular emphasis will be placed upon taking full advantage of the unique capabilities of single mode fiber technology. For example, the use of fiber couplers to increase the number of users that can be accommodated without repeaters will be investigated. Another effort will explore the use of tunable optical fibers and heterodyne detection to achieve dynamic frequency concurrency. Professors Robert Kennedy and Pierre Humblet are conducting this research.



## Estimation, Statistical Signal Processing, and Inverse Problems

A variety of stochastic estimation, analysis and signal processing problems are being studied by Professors Bernard C. Levy, Sanjoy K. Mitter, John N. Tsitsiklis, George C. Verghese, and Alan S. Willsky and their students. Theoretical studies are conducted in the areas of estimation algorithms for spatially distributed random processes, nonlinear filtering, relationships among filtering problems in scattering theory, and the analysis of large-scale systems subject to a variety of very rare events. Complementing this theoretical research are more applied projects, including the design of algorithms for detecting and compensating for sensor or actuator failures, and the development of model-based signal processing algorithms. The specific signal processing problems include the diagnosis of arrhythmias in electrocardiograms, the detection of objects or anomalies given tomographic measurements such as those made using X-rays or ultrasound in medical and industrial nondestructive testing applications, the analysis and inversion of spatially-distributed geophysical data, image processing and understanding and computational vision.

## Deterministic and Stochastic Nonlinear Dynamical Systems

The theory of nonlinear systems, both deterministic and stochastic, has developed rapidly during the last ten years. There is increasing interest in deterministic nonlinear control and various problems of adaptive control which lead to problems of nonlinear control. In the context of stochastic dynamical systems, problems of the qualitative behaviors of such systems under different time-scales are of great interest. Recent work on nonlinear filtering has shown their relationship to infinite-dimensional, bilinear systems, and there is increasing interest in the understanding of qualitative behavior of nonlinear filters for large and small time-intervals. Various investigations in this area are being conducted by Professors Athans, Mitter, Verghese, Willsky, and their students.

## Multivariable and Adaptive Control

Systematic design of multiple-input-multiple-output systems, using a unified time-domain and frequency-domain framework is an extremely active research area in the laboratory. Various theoretical and applied studies are being carried out by Professors Michael Athans, H. Austin Spang III, Gunter Stein, and Dr. Lena Valavani and their students. Theoretical research deals with issues of robustness, aggregation, and adaptive control. Recent application-oriented studies include the control of VTOL aircraft, submarine control systems, control system designs, and issues of integrated flight control.

## Theory and Algorithms for Optimization

This project focuses on analytical and computational methods for solving broad classes of optimization problems arising in engineering and operations research, as well as for applications in communication networks, control theory, power systems, computer-aided manufacturing and other areas. Currently, in addition to traditional subjects in nonlinear and dynamic programming, there is an emphasis on solution of large-scale problems involving network flows and differential and difference equation dynamics. The thrust is twofold: first, to find ways to handle the typically huge number of constraints; second, to explore the use of distributed and parallel processing to reduce the computation time needed to solve a problem and to economize on information transfer from remote data collection points to a computation center. This gives rise to fundamental issues involving the synchronization of computation and communication that are as of yet only partially resolved. Professors Dimitri Bertsekas and John Tsitsiklis and their students perform this work.

## Command, Control, and Communication Systems

The study of military Command, Communication, and Control ( $C^3$ ) systems defines basic research directions in the areas of distributed detection and estimation, distributed data bases, and team decision theory. Professors Michael Athans, Dr. Robert R. Tenney, and Dr. Alexander H. Levis, together with a large group of graduate students, are developing novel theoretical and algorithmic approaches for this rich class of system-theoretic problems.

Recent advances have been made in the following areas: (a) organization structures based on information-theoretic concepts; (b) mathematical models of distributed decision problems with limited communications; (c) multisensor-multiobject tracking algorithms including sensor scheduling; (d) integration of distributed data base systems within vulnerable communication networks; (e) development of a computer-based testbed in support of analytical research.

### Manufacturing Systems

Modeling, analysis, and control of manufacturing systems are studied by Dr. Stanley B. Gershwin, Professor Sanjoy K. Mitter, Dr. Xi-Cheng Lou, and their students. The effects of machine failures on routing and scheduling policies are investigated to reduce in-process inventories and the time spent by material in the factory. The architecture of an on-line computer system that will optimally control the flow of material is being considered. The concept of a transfer, or production, line has been extended to that of an assembly/disassembly network for the purpose of studying the interplay between reliability, speed, buffer size, production rate, and average in-process inventory levels. A special area of our activities is the Computer-Assisted Fabrication of VLSI semiconductor chips.

### Information Transfer and Retrieval

Research on information transfer and retrieval focuses on investigating issues concerning the way computer-based information systems can be engaged more easily and effectively by potential human users. These investigations involve the application of theoretical, analytical, and experimental techniques in areas such as information and computer science and technology, computational linguistics, and psychological human-factor studies.

Several current projects center on analytical and experimental investigations of expert computerized intermediary systems to assist end-users in accessing and operating heterogeneous bibliographic databases and retrieval systems. Expert assistance requires mixed-initiative (computer and human directed) actions to develop for any problem a conceptual formalization followed by an interactive process of search strategy formulation, execution, evaluation, and modification. Staff members who have supervised these efforts include Mr. Richard S. Marcus and Professor J. Francis Reintjes.

### System Reliability and Risk Management

Research on risk assessment and management is carried out in many MIT departments and laboratories. In LIDS there is interest in describing the reliability of complex systems in terms of what is known about the reliability of their components. Professor Alvin Drake has supervised research on the development of models and algorithms for studying the manner in which uncertainties about component reliabilities are reflected in uncertainty about system reliability. The primary area of application has been to low probability, high consequence risks in nuclear reactor safety. Professor Drake is also concerned with probability assessment, particularly the quantification of expert judgement.

### AWARDS

Professor John Tsitsiklis received the prestigious Presidential Young Investigator Award from the National Science Foundation.

SANJOY K. MITTER

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## Laboratory for Manufacturing and Productivity

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The Laboratory for Manufacturing and Productivity (LMP) is an Engineering School Laboratory composed of faculty, staff and students from several engineering departments. The LMP is concerned with the study and improvement of manufacturing productivity based on fundamental engineering research and the education of engineers who can provide leadership in this rapidly changing field. Our research ranges from the detailed physical process level to the general system level and covers primarily (but is not limited to) mechanical production. The work is both specific and generic, the latter seeking fundamental concepts unique to manufacturing problems, and is sponsored by a broad range of industries and government agencies. The LMP is also the base for substantial curriculum and textbook development in the manufacturing field. This is perhaps one of our most important areas of activity, principally because of the tremendous need for professionals aware of advanced manufacturing technology and because of the dearth of modern texts combined with a sustained student and industry demand for advanced subjects in this area.

Participants in the activities of the LMP include over 75 graduate students, 15 faculty from four departments (Mechanical Engineering, Materials Science and Engineering, Chemical Engineering, and Ocean Engineering), three research staff and a technical support staff. UROP students play a major role in our research, and numbered more than 40 in the past year. The LMP Reports to the Dean of Engineering, Professor Gerald Wilson, and David Hardt, Associate Professor of Mechanical Engineering, serves as Director. Dr. George Chryssolouris serves as Associate Director until his appointment to the Faculty of Mechanical Engineering in July, 1986.

The LMP derives more than 60 percent of its research support from industry, including two industry consortia, one in polymer processing and one in tribology. Currently, we have more than 25 separate sponsors from industry. The remaining support is provided by the Department of Energy, the Office of Naval Research, the National Science Foundation, the National Bureau of Standards, and the Army Materials Laboratory. In addition, the LMP Industry Collegium, which now has over 35 members, serves as an information and liaison organization for companies directly interested in manufacturing research.

### CURRENT RESEARCH

The research of the LMP can be broadly classified into two major categories: Manufacturing Processes and Manufacturing Systems. The manufacturing process research is conducted almost entirely within three programs: the MIT/Industry Polymer Processing Program, the Tribology Research Program and the Flexible Automation and Robotics Program. In addition, there is an emerging area of research dealing with advanced processing methods such as laser based systems. While all of the research in these programs is closely tied to or directly concerned with a particular process or class of processes, there exists a spectrum of objectives within this work. What ties this work together is a firm grounding in the fundamental understanding of the relevant physics in each process. This understanding is gained for several purposes: process improvement, process innovation and process control.

As process automation and control have become more mature, the collection of autonomous processes into systems has emerged as an important research topic. It is also apparent that a "systems" approach is useful even with conventional facilities. The method of integration of processes, the planning and scheduling of the systems and the interface with management functions are the primary thrusts of the new Intelligent Manufacturing Systems Program within the LMP. This program, along with the recently formed Knowledge-based Systems Program, is seeking new methods for developing rational decision making methods for both specific systems of processes and for strategic issues of product and process design.

### NEW APPOINTMENTS

Dr. Steven Kim joined the LMP on July 1, 1985, and was appointed Assistant Professor of Mechanical Engineering. Dr. Kamal Youcef-Toumi also joined the Laboratory on July 1, 1985, as a Research Associate. On January 1, 1986, he was appointed Assistant Professor of Mechanical Engineering. Both Dr. George Chryssolouris (Research Associate and Associate Director of the LMP) and Dr. Emanuel Sachs will be appointed as Assistant Professors of Mechanical Engineering effective July 1, 1986, and will join the LMP.

DAVID E. HARDT

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## Materials Processing Center

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The Materials Processing Center (MPC), formed within the Massachusetts Institute of Technology's (MIT) School of Engineering in 1980, aids the generation and transfer of scientific information necessary to promote progress in the materials processing field. Founded with a NASA grant to establish a research base in materials processing, the MPC has rapidly expanded to a current annual research budget of \$6.7 million. NASA still provides about 11 percent of the MPC's total budget, with 40 percent provided directly by industry, and another 39 percent from other governmental agencies.

### INTERDISCIPLINARY, FUNDAMENTAL RESEARCH

The MPC's basic philosophy revolves around understanding how to regulate a material's performance by controlling its internal structure, from the macroscopic to the microscopic. This control must be based on a fundamental understanding of the basic science of materials processing rather than on a purely empirical view; that is, to understand how and why a process successfully controls microstructure and subsequent properties rather than simply that it works. The MPC also attempts to increase the number of materials processing students and professionals, thereby expanding the talent base available for industry. This expansion is crucial, since requests from industry for materials research and development engineers and scientists are about three times the number of these professionals graduating.

MPC research covers a broad range of materials and activities, with a number of common themes. The foremost theme running through all MPC research is the economical control of structure, properties, and performance. In addition, projects have both practical and fundamental significance, with many related to space processing. Many researchers in both ground-based and low-gravity environment-based studies are increasing their use of mathematical modeling techniques as a research tool. The interdisciplinary nature of many projects requires the involvement of a number of faculty, staff, and students from several departments, including Chemical Engineering, Civil Engineering, Physics, Nuclear Engineering, Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemistry.

### COLLABORATION WITH INDUSTRY

Due to the rapid rate of scientific and technological innovation, new mechanisms must be developed to facilitate the transfer of scientific information and technology to industry in ways that go beyond the traditional modes of research publication and student graduation. Collaboration with industry is critically important to the university, providing academic programs with the long-term direction necessary to maintain a high degree of relevance to rapidly evolving industrial needs.

Since its inception, the Materials Processing Center has encouraged a close relationship with industry through its Industrial Advisory Board, Industry Collegium, and research consortia. The Board, whose members all come from industry and government, annually reviews the ongoing research programs and policies of the MPC, promoting direct interaction with industry. The Collegium, now with 58 worldwide corporate member companies, encourages close contact between industrial representatives and MPC personnel through workshops, visits, and tours of the research facilities. Person-to-person contact between visiting scientists from these companies and our faculty, staff, and students encourages the flow of creative ideas in both directions, while providing excellent opportunities for bilateral information and technology exchange.

The consortia, or multi-client sponsored research concept, was adopted in 1980 to promote collaborative, generic materials processing research. Late in 1985, the MPC launched its third industrial consortium, the Mathematical Modeling Laboratory (MML) Consortium under the direction of Professor Julian Szekely. Survival in any one of the extremely competitive fields of materials processing, be it steelmaking or computer memory chip production, depends on the essential tools of process optimization, on-line process control, robotization, and artificial intelligence. A quantitative mathematical process model is the first, necessary step in this direction. This program will provide the organizational framework for carrying out generic mathematical modeling research of interest to the industrial community in materials processing. The MML joins two previously organized consortia, the Ceramics Processing Research Laboratory (29 member companies) and the Materials Systems Laboratory (24 member companies). Through groups such as these, the MPC strengthens the link between basic research at the university and innovation in industry.

## EDUCATION: BEYOND THE TRADITIONAL

In addition to its research role, the MPC, through the Collegium, sponsors graduate fellowships and undergraduate summer scholarships. The fellowship program, established in 1982, endeavors to attract the very best entering graduate students to materials processing. For the 85/86 year, the MPC has offered 22 single-term fellowships to students in the Departments of Materials Science and Engineering, Electrical Engineering and Computer Science, and Chemical Engineering. The many departments involved in this program illustrate the interdisciplinary components of materials processing research and development. Similarly, the summer scholarship program, also begun in 1982, seeks to encourage undergraduate students to pursue an education and career in materials processing at MIT. For the summer of 1986, the MPC has awarded six summer scholarships to sophomores and juniors enrolled in chemistry, physics, and chemical, welding, and electrical engineering in universities throughout the United States and Canada. During the summer, these undergraduates participate in ongoing materials processing research programs before returning to their respective schools in the fall to complete their undergraduate programs.

The MPC's commitment to education goes beyond the traditional academic role: equally important is the continuing education of professionals in industry. For the third consecutive year, the MPC conducted an intensive, two-week summer course entitled "Applied Materials Technology: Materials Processing for Process-Sensitive Manufacturing" in June 1985. Seven companies sent 37 participants to sharpen their processing knowledge and skills. A similar program was organized for NASA astronauts, with MPC staff traveling to NASA's Johnson Space Center-Houston to conduct classes on various aspects of materials processing. A third seminar, the "Fundamental Research problems of Novel Steelmaking Technologies," was hosted by Professor Julian Szekely. Sponsored by the National Science Foundation, the seminar was conducted in May 1985.

## TIMELY INFORMATION EXCHANGE

Each year, the MPC hosts several workshops, each covering an area of ongoing research in materials processing at MIT, for the benefit of the Collegium member companies. The major rewards of the workshops, which have been well attended by industrial, university, and government personnel, are the timely dissemination of research results and the ensuing exchanges between speakers, Center staff, and attending industrial representatives. These workshops also provide an opportunity for graduate students to become acquainted with people in industry. Workshops held last year dealt with "Generation and Stabilization of High Technology Ceramic Powders," "Mathematical and Physical Modeling of Materials Processes," "Large-Size, Fiber-Reinforced Plastic (FRP) Structures," "Thin Film Processing," and "Advanced Materials and Processing." Workshops planned for next year will cover ceramic- and metal-matrix composites and electronic materials.

To initiate and enhance closer contact and cooperation between the materials research communities of the United States and Japan, the MPC hosted a National Science Foundation workshop on "Forefront Opportunities in Materials." Participants from both countries were encouraged to openly discuss their research on new and innovative materials. The MPC expects that contacts made during this workshop will evolve into future collaboration between American and Japanese researchers.

As part of its continuing effort to promote timely information exchange, the MPC was instrumental in launching the monthly newsletter Materials and Processing Report in April, 1986. Readership is expanding steadily, and the newsletter is rapidly becoming recognized as an authoritative source of information for the materials community. Written by its editor, Dr. Renee Ford, the newsletter reports the latest worldwide advances and developments in materials, processing, and related policy issues. The American Society for Metals, publishers of the monthly journal Advanced Materials and Processes, also contributes to the newsletter by providing two full issues annually. The newsletter is published, marketed, and distributed by the MIT Press, also a founding sponsor.

The Materials Processing Center, through its direct interaction with industrial personnel, promotes the technology transfer upon which innovation in materials processing is based. For the past six years, the MPC has provided a focus and forum in which academic, industrial, and government personnel can broaden their knowledge while collaboratively developing new scientific and technological skills in materials processing. Through such collaboration and cooperation, American industry can retain and maintain its leadership in basic processing, the keystone of high technology and advanced materials systems.

R.M. LATANISION



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## School of Humanities and Social Science

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There were a number of new initiatives and changes within the School of Humanities and Social Science this year. Several of these focused on the role of humanities, arts, and social sciences (HASS) within the Institute. An Institute-wide committee, chaired by Professor Pauline R. Maier of the History faculty, examined the HASS requirements and recommended that the current Humanities-Distribution requirements be altered to ensure that students experience a more general education within the humanities, arts, and social sciences by taking a subject in each of four areas of general knowledge (social and cultural studies, historical studies, literary studies, and the arts). This proposal is now being considered by the faculty and the Committee on the Undergraduate Program, which is evaluating it within the context of a broader reexamination of the general Institute requirements. In addition, a committee jointly sponsored by the School of Humanities and Social Science and the Office of the Dean for Undergraduate Education, chaired by Professor Leo Marx of the Program in Science, Technology, and Society, examined the possibility of developing new initiatives that would create educational programs providing greater integration between humanistic, scientific, and technical concerns. To follow up on the work of the Marx Committee, a smaller working group has been established to see what structural changes could be made within the context of existing educational programs to provide greater educational integration between the humanities and social sciences on the one hand and the sciences and engineering on the other.

As a related measure, the Integrated Studies Program, which was established two years ago as a special freshman program, has recently moved to the School of Humanities and Social Science from its initial home in the Program in Science, Technology and Society. In making this change, it is expected that the Integrated Studies Program will achieve full parity with the other freshman programs (Concourse, sponsored by the School of Engineering, and the Experimental Studies Program, sponsored by the School of Science). Although the Integrated Studies Program is only two years old, it has stimulated considerable student enthusiasm and indicates that students have a real interest in educational activities that serve to link the humanistic and scientific worlds.

Two other initiatives were also aimed at breaking down the existing barriers between these two cultures: one related to students and one related to faculty. This winter the Burchard Scholars Program was established to recognize MIT undergraduates whose primary interest is in science and engineering but who have demonstrated exceptional interests and ability in the humanities, arts, or social sciences. Fifteen Burchard Scholars were appointed in February, and throughout the winter term, they met regularly over dinner with a number of faculty within the School of Humanities and Social Science to discuss a paper of general interest. In addition, this summer two faculty mini-courses were given to create links between the School of Engineering and the School of Humanities and Social Science. In one, faculty members from the Department of Electrical Engineering and Computer Science provided a one week version of 6.001 Structure and Interpretation of Computer Programs to over 30 faculty members from the School of Humanities and Social Science from such diverse disciplines as Literature, Foreign Languages and Literatures, Linguistics, Philosophy, Economics, and Political Science. In the other mini-course, faculty members in History and Political Science presented a one week course on current world problem areas (Lebanon, South Africa, China, India, and Japan) to over 30 faculty members from the School of Engineering. In both cases, all of the faculty involved felt that the courses were extremely successful, and we expect to expand the range of faculty-to-faculty seminars in the coming year.

In another cooperative venture, the Schools of Humanities and Social Science and of Engineering have sponsored a three year experiment in which Japanese is taught at MIT through the MIT-Wellesley Exchange. This past year Assistant Professor Michio Tsutsui of Wellesley has taught beginning and intermediate Japanese to MIT students. Next year these offerings will be expanded to include advanced Japanese and Professor Tsutsui will be assisted by a lecturer. This experiment is being closely evaluated to determine if there is sufficient student interest to introduce Japanese formally into the MIT curriculum.

In spite of the many initiatives that are underway to bring the humanities, arts, and social sciences to a more central role within the undergraduate curriculum, the Departments, Sections, and Programs within the School of Humanities and Social Science continue to play a largely service role with respect to undergraduate education. Students typically take few subjects in excess of Institute requirements in the humanities, arts, and social sciences, and there continue to be relatively few majors in the HASS disciplines. Economics and Foreign Languages and Literatures continue to be the most popular areas of concentration, while Literature, History, and Foreign Languages and Literatures draw the greatest number of students within the distribution requirement. The lack of real commitment of the typical MIT undergraduate to subjects within the HASS requirements continues to be a source of frustration and concern to the faculty within the School, who remain cautiously optimistic concerning the various educational initiatives that are currently underway within the School and the rest of the Institute.

Effective the beginning of the current fiscal year, the Psychology Department will move to Whitaker College and change its name to the Department of Brain and Cognitive Sciences. Since this new department will encompass activities ranging from neurobiology to cognitive science, it is hoped that it will create an intellectual environment that will expand the frontiers of knowledge related to the brain and cognitive sciences and develop an understanding between these two areas. Although the Psychology Department will formally leave the School of Humanities and Social Science, the undergraduate offerings in social psychology will remain part of the HASS curriculum.

In another administrative change effective July 1, 1986, the Statistics Center will move to the School of Humanities and Social Science as part of an effort to broaden the base of statistics within the Institute and to develop new initiatives for statistics within the social and management sciences. Professors Daniel McFadden and Roy Welsch, respectively of the Economics Department and Sloan School, will serve as the Center's co-directors and work to strengthen the role of statistics within the Institute's curriculum (both graduate and undergraduate) and broaden the Center's base of research and of faculty support.

The drama and dance activities were also reorganized this past year to create a more unified and coordinated program. A new position of Coordinator for the Performing Arts has been established, which oversees the activities of Dramashop, the Dance Workshop, and the Shakespeare Ensemble. Professor Marcus Thompson of the Music faculty is currently serving in this capacity.

The History faculty recently moved to E51. Thus the East Campus now houses a large social science community consisting of Economics, Political Science, History, and the Program in Science, Technology and Society. In addition to providing much needed relief in the overcrowded condition in Building 14, it is hoped that the move of the History faculty will serve to strengthen the ties within the School's social science community.

The faculty within the School of Humanities and Social Science received a number of honors and awards this past year. Most notable was the award of the Nobel Memorial Prize in Economics to Professor Franco Modigliani of the Department of Economics. In addition Professor Jerry A. Hausman of the Economics Department received the John Bates Clark Medal of the American Economic Association, which is awarded biannually to a distinguished economist under 40. Professor Bruce Mazlish of the History faculty received the Toynbee Prize for his pioneering work in psychology and history and Professor Emilio Bizzi of the Psychology Department was elected to the National Academy of Sciences. Professor Loren Graham of the Program in Science, Technology and Society and Professor Robert M. Solow of the Economics Department each received an honorary degree, the former as Doctor of Letters from Purdue and the latter as Doctor of Social Science from Yale. A number of the faculty in the Economics Department served as officers of economics professional organizations: Professor Daniel M. McFadden as President of the Econometric Society, Professor Emeritus Charles Poor Kindleberger as President of the American Economic Association, and Professor Peter A. Diamond as Vice President of the American Economic Association. Assistant Professor John Hildebidle of the Literature faculty received the John Gardner Award for short fiction.

Three faculty members within the School of Humanities and Social Science retired after many years of distinguished service: Institute Professor Walle Nauta of the Psychology Department and Professors E. Cary Brown and Robert L. Bishop, both of the Department of Economics. Professor Nauta, a noted neuroanatomist and teacher, has done pioneering work in the brain sciences. A distinguished theorist, Professor Bishop had also served as Head of the Department of Economics and Dean of the School of Humanities and Social Sciences. A noted scholar in the field of public finance, Professor Brown has devoted himself to administration over the last two decades, serving as Head of the Economics Department from 1965-1983, and most recently as Head of Foreign Languages and Literatures and Associate Dean of the School of Humanities and Social Science. The collective wisdom of these distinguished members of the MIT community will be greatly missed by the School and the Institute.

I am sorry to report on the deaths of three faculty members within the School. Professor Edwin M. Kuh of the Economics Department, Professor Emeritus Roy Lamson of the Department of Humanities, and Professor Emeritus Harold Isaacs of the Political Science Department. Their presence, style, and contributions will be greatly missed.

ANN F. FRIEDLAENDER



TABLE I  
Enrollment in Humanities, Arts and Social Science Subjects:  
1985-86

Field	Elective Subjects		Distribution Subjects		Totals	
	# of Subjects	# of Students	# of Subjects	# of Students	# of Subjects	# of Students
Anthropology/ Archaeology	13	123	8	116	21	239
Economics	21 <sup>52</sup>	1280	3	37	24 <sup>55</sup>	1317
Foreign Languages & Literatures	48 <sup>80</sup>	1086	26 <sup>42</sup>	632	74 <sup>122</sup>	1718
History	25	258	18 <sup>19</sup>	669	43 <sup>44</sup>	927
History of Art & Architecture	2	60	4	189	6	249
Interdisciplinary	4	36	1	28	5	64
Linguistics	1	25	2 <sup>5</sup>	190	3 <sup>6</sup>	215
Literature	23	332	23 <sup>32</sup>	870	46 <sup>55</sup>	1202
Music	20 <sup>26</sup>	463	8 <sup>22</sup>	367	28 <sup>48</sup>	830
Philosophy	12	219	9	389	21	608
Political Science	26	312	13	401	39	713
Psychology	10 <sup>11</sup>	782	0	0	10 <sup>11</sup>	782
Science, Technology & Society	15	72	11	263	26	335
Urban Studies	3	17	4	42	7	59
Visual Arts & Design	18	466	3	106	21	572
Theatre and Dance: Performance	4 <sup>5</sup>	35	0	0	4 <sup>5</sup>	35
Traditions & Texts	0	0	4 <sup>6</sup>	139	4 <sup>6</sup>	139
Writing	21 <sup>37</sup>	451	8 <sup>20</sup>	269	29 <sup>57</sup>	720
TOTALS	266 <sup>353</sup>	6017	145 <sup>202</sup>	4707	411 <sup>555</sup>	10724

NOTE: Figures were obtained from the grade/subject distribution report which shows the final tally for each class. The numbers shown are for undergraduate subjects which normally satisfy the HASS Requirement; they do not include subjects allowed towards the Requirement only upon petition. Superscript is number of autonomous class sections if more than one; this does not apply to subjects which meet in a single lecture once or twice a week and divide into discussion sections for a single meeting.

TABLE II: Concentrations in All Fields of Humanities, Arts, and Social Sciences\*  
June 1986

Fields of Concentration	Class of 1989	Class of 1988	Class of 1987	Class of 1986	Totals in Fields
American Studies	( 0 ) 0	( 2 ) 0	( 4 ) 1	( 8 ) 6	( 14 ) 7
Ancient & Medieval Studies	( 0 ) 0	( 3 ) 0	( 1 ) 1	( 13 ) 12	( 17 ) 13
Anthropology/Archaeology	( 1 ) 0	( 1 ) 0	( 6 ) 0	( 10 ) 10	( 18 ) 10
Economics	( 3 ) 0	( 73 ) 11	(123) 44	( 273 ) 247	( 472 ) 302
Film & Media Studies	( 0 ) 0	( 0 ) 0	( 5 ) 0	( 12 ) 12	( 17 ) 12
Foreign Languages & Literatures**	( 3 ) 0	( 75 ) 16	(162) 64	( 202 ) 188	( 442 ) 268
History	( 0 ) 0	( 13 ) 0	( 40 ) 14	( 53 ) 50	( 106 ) 64
History of Art & Architecture	( 0 ) 0	( 1 ) 0	( 3 ) 0	( 9 ) 9	( 13 ) 9
Labor in Industrial Society	( 0 ) 0	( 0 ) 0	( 0 ) 0	( 0 ) 0	( 0 ) 0
Latin American Studies	( 0 ) 0	( 1 ) 0	( 1 ) 0	( 2 ) 2	( 4 ) 2
Linguistics	( 0 ) 0	( 4 ) 0	( 1 ) 1	( 6 ) 6	( 11 ) 7
Literature	( 1 ) 0	( 25 ) 1	( 63 ) 7	( 119 ) 110	( 208 ) 118
Music	( 0 ) 0	( 52 ) 1	( 55 ) 7	( 68 ) 55	( 175 ) 63
Philosophy	( 0 ) 0	( 10 ) 1	( 24 ) 0	( 63 ) 60	( 97 ) 61
Political Science	( 2 ) 0	( 10 ) 9	( 34 ) 11	( 52 ) 50	( 98 ) 70
Psychology	( 5 ) 0	( 26 ) 2	( 48 ) 7	( 69 ) 61	( 148 ) 70
Russian Studies	( 0 ) 0	( 0 ) 0	( 0 ) 0	( 4 ) 3	( 4 ) 3
Science, Technology, & Society	( 0 ) 0	( 1 ) 0	( 7 ) 1	( 28 ) 21	( 36 ) 22
Theatre Arts	( 0 ) 0	( 1 ) 0	( 7 ) 1	( 13 ) 11	( 21 ) 12
Traditions & Texts	( 0 ) 0	( 0 ) 0	( 3 ) 1	( 9 ) 9	( 12 ) 10
Urban Studies	( 0 ) 0	( 0 ) 0	( 1 ) 0	( 6 ) 6	( 7 ) 6
Visual Arts & Design	( 0 ) 0	( 7 ) 0	( 23 ) 1	( 28 ) 21	( 58 ) 22
Women's Studies	( 0 ) 0	( 0 ) 0	( 7 ) 2	( 4 ) 3	( 11 ) 5
Writing	( 2 ) 0	( 18 ) 0	( 34 ) 2	( 67 ) 57	( 121 ) 59
Special Concentrations	( 0 ) 0	( 7 ) 1	( 25 ) 7	( 42 ) 42	( 74 ) 50
TOTALS	(17) 0	(330) 42	(676) 172	(1160) 1051	(2184) 1265

\* The parenthetical figure is the number of proposed concentrations in the given class and field; the figure to its right is the number of these concentrations that have been completed.

\*\* Figures for subfields of Foreign Languages and Literatures:

French	( 0 ) 0	( 30 ) 6	( 54 ) 26	( 60 ) 57	( 144 ) 89
German	( 2 ) 0	( 17 ) 5	( 39 ) 18	( 49 ) 49	( 107 ) 72
Russian	( 0 ) 0	( 5 ) 0	( 14 ) 5	( 24 ) 18	( 43 ) 23
Spanish	( 0 ) 0	( 12 ) 4	( 34 ) 8	( 41 ) 41	( 87 ) 53
World Literature in Translation	( 0 ) 0	( 2 ) 0	( 5 ) 2	( 10 ) 9	( 17 ) 11
Other Languages	( 1 ) 0	( 9 ) 1	( 16 ) 5	( 18 ) 14	( 44 ) 20

TABLE III

Undergraduate Majors in the School of Humanities and Social Science\*

Year	Economics	Humanities**	Philosophy	Political Science	Psychology***	TOTAL
1974-75	63	48	1	14	--	126
1975-76	67	41	3	24	--	135
1976-77	67	31	7	25	--	130
1977-78	52	34	7	21	--	114
1978-79	48	38	5	30	--	121
1979-80	44	37	9	36	--	126
1980-81	50	40	11	30	--	131
1981-82	51	49	9	32	--	141
1982-83	48	37	7	28	11	131
1983-84	48	24	3	22	20	117
1984-85	52	30	2	15	27	126
1985-86	51	52	5	26	34	168

\* As registered in the second term of academic year 1974-75 to 1985-86. Data taken from the Registrar's fifth-week report.

\*\* These figures do not include double majors who registered first in a course other than Humanities.

\*\*\* Undergraduate degree in Cognitive Science, instituted in 1982-83.

TABLE IV

Graduate Students in the School of Humanities and Social Science\*

Year	Economics	Linguistics & Philosophy	Political Science	Psychology	TOTAL
1974-75	114	53	95	25	287
1975-76	120	49	89	27	285
1976-77	114	46	91	29	280
1977-78	123	45	102	24	294
1978-79	121	48	96	28	293
1979-80	138	63	143	36	380
1980-81	126	66	121	32	345
1981-82	111	55	142	26	334
1982-83	136	51	163	27	377
1983-84	113	52	99	25	289
1984-85	108	53	121	30	312
1985-86	130	59	171	35	395

\* As registered in the second term of academic year 1974-75 to 1985-86 (including special graduate students). Data taken from the Registrar's fifth-week report.

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## Humanities Undergraduate Office

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For the Humanities Undergraduate Office, 1985-86 has brought an increased volume of contact with students in both its Institute-wide Humanities, Arts, and Social Sciences (HASS) operations and its administering of degree programs under Course XXI. The year has also been marked by a special event of considerable importance, the Course XXI Convocation. In general things have gone very well, although in at least one area there is need for improvement via policy change. Director Travis Merritt and Coordinator Ruth Spear will miss the collegueship of Shawn Finnegan, whose stint as Course XXI Administrative Assistant comes to a close in June.

### HUMANITIES, ARTS, AND SOCIAL SCIENCES (HASS) INFORMATION CENTER

The HASS Center has maintained its various services to MIT students, faculty, and administration, as defined in earlier years. The principal change has been a distinct increase in the number of students who make use of the Center and its publications. Several items require brief discussion here:

#### HASS Enrollment Statistics by Field and Subject

The subject-by-subject enrollment statistics for all HASS Fields, now covering 14 consecutive semesters, present a substantial opportunity for the organization and interpretation of data, leading to a clearer view of the academic habits of MIT undergraduates under the Institute's HASS Requirement. So far relatively little has been done with these data, aside from the rough plotting of comparative sum enrollments. We expect to undertake the early phase of more interpretive study next year, working in conjunction with the Registrar and the Office of the Dean for Student Affairs. The acquisition of more advanced computer hardware and software should prove helpful to this effort.

#### HASS Concentrations: Patterns of Popularity

Measured in terms of both total declared concentrators and those in the graduating class, the most popular fields continue to be Economics (472, 273), Foreign Languages and Literatures (442, 202), and Literature (208, 119). At the other end of the spectrum, there are a dozen fields none of which has had as many as 15 concentrators in either of the last two graduating classes. It would not be difficult to argue for a reduction in the length of the list of fields, by aggregation, and a strengthening of those that remain.

#### Harvard Cross-Registration: Significant Increases

The coordinating and monitoring of cross-registration by MIT students at Harvard is part of the ongoing business of the Humanities Undergraduate Office. This year brought a more than 33 percent increase in the number of Harvard subjects taken by our undergraduates. Languages (especially Japanese and Chinese) and Economics are the pace-setters, but there have also been conspicuous increases in Literature, History, and Psychology. While the total number of registrations remains at a modest level -- roughly 200 per year -- the upward swing suggests a bit more academically adventurous spirit among our students, particularly in humanistic areas.

### COURSE XXI

#### Course XXI Thirtieth Anniversary Convocation

Course XXI marked the completion of its first three decades with an October weekend convocation which included a good deal of eating and socializing as well as an array of talks, panel discussions, demonstrations, and concerts. Friday afternoon's activity focussed on two special presentations: "A Visit to the Center for Materials Research in Archaeology and Ethnology -- How Modern Archaeology Views the Past: the Engineering of Materials in Prehistory," with talks by Heather Lechtman, Professor of Archaeology and Ancient Technology, Arthur Steinberg, Associate Professor of Archaeology, Suzanne De Atley, Assistant Professor of Archaeology, Frederick Wiseman Principal Research Scientist in Archaeology; and "Learning Foreign Languages -- Getting Around Vocabulary and a Vocabulary for Getting Around," with demonstrations and dramatizations by Catherine Chvany, Professor of Russian, Gilberte Furstenberg, Lecturer in French, Claire Kramsch, Senior Lecturer in German, Douglas Morgenstern, Lecturer in Spanish and other members of the Foreign Languages and Literatures faculty.

At the Convocation dinner on Friday evening, Ann F. Friedlaender, Dean of the School of Humanities and Social Science, delivered the keynote address, "Technology and Liberal Education."

Saturday morning saw strong attendance at two panel discussions: "How the Middle East Sees America: An Historical Overview," with Philip Khoury, Associate Professor of History, Bernard Avishai, Associate Professor of Writing, Tina Bahadori '84, XXI-E; and "Is the Theatre Dead -- Again?" with A.R. Gurney, Jr., Professor of Literature, Robert Scanlan, Director, MIT Dramashop, Derek Campbell, Director, MIT Shakespeare Ensemble, and Theo Theoharis, Assistant Professor of Literature.

Following luncheon at the MIT Museum, a large and lively audience joined a diverse panel in discussion of the Convocation's central theme: "How Many Cultures Now? -- What an Educated Person Should Know." Participants: Peter Buck, Associate Professor of the Social Study of Science, Isabelle de Courtivron, Associate Professor of French, Anthony French, Professor of Physics, John Harbison, Professor of Music, Jerome Lettvin, Professor of Electrical and Bioengineering and Communication Physiology, George McQuilken '65, XXI-A, Travis Merritt, Professor of Literature, Roslyn Romanowski '82, XXI-B1, Lauren Seeley '86, XXI, Irene Tayler, Professor of Literature and Leon Trilling, Professor of Aeronautics and Astronautics.

The Convocation concluded with music by members of the MIT Chamber Music Society, MIT Brass Ensemble and MIT Festival Jazz Ensemble and a viewing of a retrospective exhibition, in the Building 14 Corridor Gallery, on the Humanities and Course XXI at MIT.

The event brought back to the campus more than 70 alumni and alumnae, constituting the highest percentage of graduates ever to attend any similar departmentally sponsored occasion at MIT. Current Humanities faculty, emeriti, and current Course XXI students were also strongly represented. With many of its events open to the MIT community at large, the Convocation helped to strengthen the visibility and reputation of Course XXI among the undergraduate population.

#### Students: Growth in Numbers

At the close of the 1985-86 academic year, the total number of students enrolled in Courses XXI, XXI-E, and XXI-S stood at 111, a 41 percent increase over the 1984-85 figure of 79, and the largest single-year gain since 1968-69. Certainly some of this can be attributed to the enhanced visibility of the programs, aided materially by the Course XXI Convocation in October and by the currency of the "dual literacy" concept which has attended recent discussions of the restructuring of MIT undergraduate education. But it is also worth noting that the field of Literature alone accounted for half of the overall increase, and that the composite area of "letters" -- Literature, Foreign Languages and Literatures, and Writing -- has increasingly attracted the highest density of population, with a combined total of 65 (as compared, for instance, with 14 from the grouping Anthropology/Archaeology, History, and STS).

Enrollments in the Humanities and Science major (XXI-S) was sharply up (by 131 percent) the full Humanities major (XXI) enjoyed a substantial increase (36 percent) while Humanities and Engineering (XXI-E) remained constant. Nearly half of the XXI-S majors chose Biology as their science field, a fact largely symptomatic of the long-awaited and welcome return to this degree program, in significant numbers, of students interested in medicine.

The academic performance of majors in all these programs maintained the relatively high levels of recent years, with a collective cumulative average of 4.1 (4.1 for XXI, 3.9 for XXI-E, 4.1 for XXI-S). Perhaps more significantly, students pursuing more than one degree out-performed single-degree candidates by a margin of 4.3 to 3.9.

#### Degrees, Distinctions, and Post-Graduation Plans

One student received the S.B. in September 1985 (one in XXI-E), three in February 1986 (two in XXI, one in XXI-E), and 17 in June (four in XXI, seven in XXI-E, six in XXI-S), a total of 21 for the academic year.

Class of 1986 graduates are headed for further study at the Stanford School of Medicine, the Harvard School of Medicine, the University of California at Davis School of Medicine, the Kennedy School of Government at Harvard, and the graduate program in Technical Communication at Carnegie-Mellon. Prospective places of employment include Ulysses Inc. of Cambridge, Intel Corporation, Cambridge Business Systems, The New York Times, Public Broadcasting (NOVA), and G&H Soho of New York.

As usual, dozens of XXIers distinguished themselves by taking leadership roles and by winning a variety of honors and awards.

TRAVIS MERRITT

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## Department of Economics

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The illness and death of Professor Edwin Kuh cast a pall over this year. His presence, style, and contribution will all be missed.

The Economics Department continued its exceptional record of attracting a large fraction of the best graduate students nationwide including a higher than normal fraction of NSF fellows who were just beginning their graduate study. This success, while very welcome, highlighted the continued dependence of the Department on the NSF Fellowship Program. While the Department has continued raising money for fellowship support, much more is needed to protect against possible further cuts in that program.

To complement Athena, which provides computing facilities for undergraduate and beginning graduate courses, the Department is planning a student PC complex for advanced graduate courses and thesis writing students. This complex will contain machines generously donated by AT&T. It is hoped to have the complex up and running by the start of the fall semester.

The faculty continue to be highly productive and to publish research over a wide range of economic topics. Examples of titles published this year include "Is the Strong Dollar Sustainable?" (Professor Paul R. Krugman), "Stopping Hyperinflations Past and Present" (Professors Rudiger Dornbusch and Stanley Fischer), "Procurement and Renegotiation" (Professor Jean Tirole), "Economic Issues of Standardization" (Professor Garth Saloner), and "Price Destabilizing Speculation" (Professor Oliver Hart). Professor Franklin Fisher's lectures in microeconomics will be published by Wuhan University Press in Chinese.

In terms of honors, Institute Professor Franco Modigliani's Nobel Prize was the most visible of the Department's successes. His Nobel lecture, "Life Cycle, Individual Thrift and the Wealth of Nations" was expanded into his two Killian Award Lectures: (1) "The Life Cycle Hypothesis" and (2) "Applications of the Life Cycle Hypothesis to Policy Issues." Professor Modigliani also received the Cavaliere di Gran Croce and two honorary degrees. Institute Professor Robert Solow received an honorary degree from Yale. Professor Jerry Hausman received the John Bates Clark Medal from the American Economics Association. During the year, Professor Fischer held a Guggenheim Fellowship while Professor Tirole held a Sloan Research Fellowship. Professors Peter Temin and Martin Weitzman were elected fellows of the American Academy of Arts and Sciences. Professor Olivier Blanchard was elected a fellow of the Econometric Society and received the Best Teacher Award from the Graduate Economics Association. Professor Fischer was awarded the Graduate Student Council Teaching Award. Professor Dornbusch gave the first Lionel Robbins Lectures at the London School of Economics while Professor Lance Taylor gave the first W. Arthur Lewis Lecture to the National Economics Association. Professor Hart was Hooker Distinguished Visiting Professor at McMaster University in November. Professor Daniel McFadden served as President of the Econometric Society. Professor Charles Kindleberger served as President and Professor Peter Diamond as Vice-President of the American Economics Association. Professors Diamond and Hart continued on the Council of the Econometric Society while Professor McFadden continued on the Executive Committee of the American Economics Association.

Associate Professor Henry Farber was promoted to Professor and Assistant Professor James Poterba to Associate Professor. During the year Professor Temin was Pitt Professor of American History and Institutions at Cambridge University. Professor Paul Joskow was on leave at the Center for Advanced Studies in Behavioral Sciences. Professor Michael Piore was on leave at the Centre d'Etude de l'Emploi in Paris and the Institute for Labour Studies in Geneva. Professor James Powell was on leave dividing his year between Carnegie-Mellon University and the University of Wisconsin. Professor Powell has elected to stay on at the University of Wisconsin rather than return to MIT. One new appointment has been made for the coming year. Jeffrey Wooldridge of the University of California at San Diego will join the Department as an assistant professor. Professor Weitzman has been appointed Mitsui Professor in Problems of Contemporary Technology, replacing Professor Piore. During the year the Department had a number of distinguished visitors: Professors Eytan Sheshinski of Hebrew University in Jerusalem and David Galenson of the University of Chicago were at MIT for the fall; Professor John Abowd of the University of Chicago Graduate School of Business was at MIT for the entire year; Professor Steven Salop of Georgetown University Law School was at MIT for the spring.

This year marks the retirement of two faculty members who have been at the Institute for a very long time. Professor Robert L. Bishop joined the faculty in 1942 and Professor E. Cary Brown joined in 1947. Happily both will continue to be active in the Department during their retirement.

PETER A. DIAMOND

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## Department of Humanities

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### Anthropology/ Archaeology Section

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The Program hosted seminars this year by Professor Martin Diskin and Professor James Howe who discussed research aspects of their recent field trips to Nicaragua and Panama respectively. We also co-sponsored an Institute-wide symposium on Politics and Culture of Latin America. Dr. Frederick Wiseman, with the help of students, began excavation of an archaeological site near Gloucester, MA; he also set up the Program's computer facility which we plan to use in our teaching.

Program faculty continued to be productive in their research endeavors. Two colleagues were in the field: Professor Howe in Washington and Panama doing archival and field work on the Marsh Darien Expedition and the Kuna Revolution of 1924-25, and Professor Sharon Traweek in Japan studying the ethnography of the high energy physics community. Professor Howe's book The Kuna Gathering: Village Politics in Contemporary Panama appeared this summer while Professor Traweek's book "Buying Time and Taking Space: An Ethnography of the High Energy Physics Community" was accepted for publication by the Harvard University Press. The faculty at home worked and published papers on a very wide variety of topics: Professor Suzanne DeAtley on various aspects of ceramic technologies in archaeological contexts, on the ethnography of Japanese ceramic production, and continues work on an atlas of firing alterations in ceramics; Professor Diskin on agrarian reform in El Salvador, ethnic autonomy in Nicaragua, and indigenous economic structures in Oaxaca, while also giving a great number of talks on the problems in El Salvador and Nicaragua; and Professor Jean Jackson on gender roles in various societies and on the anthropologist's use and perception of her fieldnotes. She also received major funding for her research project on the building of therapeutic communities as observed in the Boston Pain Center. Professor Heather Lechtman concluded her work on the properties of copper-arsenic alloys and their uses and methods of manufacture in ancient societies, while continuing to direct the Center for Materials Research in Archaeology and Ethnology. Professor Arthur Steinberg continued work on the revolution in 16th century Venetian painting technique and style and, with Professor Jonathan Wylie, on the social context for that change, while also organizing a major purchase of microcomputers for the School of Humanities and Social Sciences. Dr. Wiseman did pollen studies in both the Maya area and colonial North America as well as more general work on agriculture and vegetation dynamics of the Maya area. Professor Wylie continues work on the comparative economies of maritime societies and on Caribbean marine ecosystems.

Students working with faculty members in the Program won an uncommonly large number of awards over the last two years. Raymond Meilunas, working with Professor Steinberg on the analysis of aged paint binders and the adaptation of linseed oil in Renaissance painting, won an Eloranta Fellowship and the Wolfe award last year, while this year he won the Best Senior Thesis award in Materials Science and Engineering for a part of this work. Melissa Krawiczki and Matthew Lewis won the Wolfe award for work done with Professor Lechtman on the technology and use of West Mexican tweezers. Brenda Golianu won an Eloranta Fellowship for work on cross-cultural studies of the doctor-patient interaction, supervised by Professor Jackson.

The only personnel change this year is that Professor DeAtley is leaving MIT to conduct independent research.

Visitors to the Program this year included Dr. Niels Braroe who is writing a book on the anthropological analysis of acculturation; and Peter Lacovara from the Egyptian Department at the Boston Museum of Fine Arts who taught a course on the Archaeology of Egypt.

ARTHUR STEINBERG

Although budgetary constraints forced reductions in the subject offerings of the Section this year and somewhat increased the class size, total enrollment of 1,748 was only slightly smaller than last year with no marked shifts between languages. Undergraduate concentrators in languages continue to number the second largest humanities concentration. To get a clearer picture of the motivations of our students a survey of this term's foreign language classes was made. It indicated that the vast majority of students took foreign languages to satisfy cultural or liberal-education needs rather than for professional reasons. Two highly successful student performances were developed in undergraduate drama workshops: Assistant Professor Manuel Delgado presented an evening of three one-act plays from Mexico, Argentina, and Chile; Associate Professor Michael Geisler directed Brecht's Das Leben des Galilei.

The major curricular initiative was in Japanese. A three-year experimental program was launched under the sponsorship of the Deans of Engineering and of Humanities and Social Science with the cooperation of Wellesley College. Assistant Professor Michio Tsutsui, appointed by Wellesley College this year, was director of the program. Despite the failure of class capacity to meet demands, the program was a success. Next year this experiment will be expanded by the addition of a lecturer.

Two international conferences at MIT were jointly sponsored by the Section. Assistant Professor Suzanne Flynn directed an NSF-financed three-day discussion, jointly sponsored by the Department of Linguistics and Philosophy, of "Linguistic Theory and Second Language Acquisition" (Wayne O'Neil, Professor of Linguistics, was assistant director). The high quality of the conference papers and interest in the subject will result in their publication shortly by the Reidel Press. The second conference--"Culture and Conflict in Central America"--was sponsored by several academic units of the School and co-moderated by Associate Professor of Spanish, Elizabeth Garrels.

A number of research monographs are nearing final revision but have not yet been published. The first volume of an innovative textbook series on communicative strategies in language, coordinated by Senior Lecturer Claire Kramsch, has appeared; she and Lecturer Ellen Crocker were coauthors of the text entitled Reden, Mitreden, Dazwischenreden.

The faculty continues its active involvement in professional activities. Professor Catherine Chvany in addition to serving on several editorial boards has been appointed editor of Folia Slavica, elected for a four-year term to the Executive Committee of the General Linguistics Group of the Modern Language Association, and continues as Fellow of Harvard's Russian Research Center; Associate Professor Isabelle de Courtivron was appointed member of the commission on the Status of Women in the Profession of the MLA; Associate Professor Kathryn Crecelius served on the Selection Committee for the American Council of Learned Societies' Fellowships; next year Lecturer Robert Di Donato will become President of the American Association of Teachers of German; Senior Lecturer Kramsch was Director of the Northeast Conference on the Teaching of Foreign Languages; Assistant Professor Edith Waldstein is President of the Massachusetts Chapter of the American Association of Teachers of German, Chairman of the 19th Century German Literature Session of the New England MLA, and Editor of the Women in German Yearbook.

I report with pleasure that Senior Lecturer Kramsch has been appointed Professor of Foreign Language Acquisition, and Assistant Professor Geisler promoted to Associate Professor of German; and with regret that Assistant Professor Delgado resigned.

E. CARY BROWN



The most dramatic change of 1985-86 for the History Faculty was its move from building 14, its home for the past 40 years, to new and less crowded quarters in building E51, where it hopes to contribute toward a more broad-ranging "social science complex" on the East Campus.

The year was notable also in that four members of the History Faculty either published books or had books accepted for publication. Michael McGerr's The Decline of Popular Politics: Political Life in the North, 1856-1928 was published by Oxford University Press early in 1986, and Philip Khoury's Syria and the French Mandate: The Politics of Arab Nationalism, 1920-1945 will be published by Princeton University Press later in that year. Peter Perdue's Exhausting the Earth: State and Peasant in Hunan, 1500-1850 is scheduled for publication by Harvard University Press in the spring of 1987; and Sarah Deutsch's Culture, Class, and Gender: Chicanas and Chicanos in Colorado and New Mexico, 1900-1940 will probably also be issued, by Oxford University Press, in 1987. Pauline Maier published an American history textbook for junior high school students, The American People: A History (D.C. Heath, 1986), and a study entitled "The Pope at Harvard: The Dudleian Lectures, Anti-Catholicism, and the Politics of Protestantism," which will be published in the Proceedings of the Massachusetts Historical Society for 1985.

Another senior member of the History Faculty, Bruce Mazlish, was awarded the Toynbee 1986-87 Prize for his pioneering work on psychology and history. The Toynbee Prize is awarded biannually for outstanding contributions to the social sciences. Previous recipients include Raymond Aron, Lord Kenneth Clark, Buckminster Fuller, and Jean-Paul Sartre. Mazlish has published several books, including studies of James and John Stewart Mill, Karl Marx, Richard Nixon, Jimmy Carter, and Henry Kissinger.

Historians were unusually prominent in Institute affairs this year. Pauline Maier was chair of the committee charged with proposing a revision of the General Institute Requirements in the Humanities, Arts, and Social Sciences. Philip Khoury served on both the committee to design an integrative program in the liberal arts, chaired by Leo Marx of the STS faculty, and on the committee reexamining the rules on Institute service, chaired by Donald Holland of the Sloan School. Khoury organized, won financing for, and chaired the Emile Bustani Middle East Seminar of the Center for International Studies at MIT, which was officially inaugurated in 1985. With Bruce Mazlish, he also organized a new program for 13 sophomores and juniors who have demonstrated excellence in the humanities and social sciences. Those students, named Burchard Scholars after the first dean of the School of Humanities and Social Science, meet for monthly dinners at which some member of the MIT faculty, a visiting scholar, or perhaps one of the Burchard Scholars presents a talk on a topic of general interest, which is followed by discussion. The Burchard Scholars program was begun in 1986 under the sponsorship of Ann F. Friedlaender, Dean of Humanities and Social Science, and has been one of the year's more successful experiments.

The academic year 1985-86 may be notable in MIT history for marking new liaisons between the different schools of the Institute, and historians played an active role in those initiatives. Robert Rotberg organized a summer seminar for members of the School of Engineering entitled "Looking at the World: Ways of Understanding Global Politics." Speakers included, aside from Rotberg, Lucian Pye, Richard Samuels, and Myron Weiner of the Department of Political Science as well as Philip Khoury of the History Faculty. And four members of the History Faculty -- Robert MacMaster, Bruce Mazlish, Peter Perdue, and David Ralston -- took a version of 6.001, The Structure and Interpretation of Computer Programs, offered in June for faculty members in the School of Humanities and Social Science. It should be noted, too, that ten members of the History Faculty participated in a special IAP offering on "Social Conflict:...its Causes and Nature."

The most important personnel action of the year lay in the award of tenure to Philip Khoury, an action whose appropriateness is witnessed in part by his repeated appearance in this brief summary of the year's activities. Only Robert Fogelson, who holds a joint appointment in Urban Studies and Planning and in History, was on leave during 1985-86, but next year Richard M. Douglas will be on sabbatical leave during the fall term, and Michael McGerr will be on leave under the Old Dominion program in the spring. The rest of the faculty will be present, hopefully realizing the intellectual opportunities as well as appreciating the relative luxury of its new quarters.

PAULINE MAIER

The Literature Faculty this year numbered 29 students among its majors -- a higher number by a factor of three than it could boast since the mid-sixties and one larger than any other section of what used to be the Department of Humanities. The presence of this number is not an unmixed blessing. The faculty at full strength numbers only 15 -- about the size of a small English or Comparative Literature department at a liberal arts college -- and must fulfill a primary obligation to staff a range of subjects (last year enrolling over 1200 students and averaging over 20 students per section) for both distribution and concentration, the latter function engaging over 200 students as a rule and requiring a three-tiered curriculum, culminating in a seminar tier, each subject of which is supposedly limited to no more than 12 students. The increase in majors has meant that the limitation on student enrollments in the seminar tier cannot be observed and that a need has arisen for a new seminar for majors, which rightly should be taught in two sections. At the same time, the chronic understaffing of subjects in literature was particularly acute this year, since four of our 15 faculty were away on full-time leaves of absence and three on half-time leaves of absence. These leaves are one result of the professional success of the staff; those familiar with the paucity of grants and honorary appointments in the humanities (approximately 0.5 percent of applications are successful) will appreciate that it would be both unwise and unfair to refuse faculty in receipt of them the opportunity to accept them. The situation is bound to alleviate itself, since receipt of an award one year usually has the effect of unofficial disqualification for other awards for several years to come, but it will nonetheless still be problematic; for it will remain necessary to utilize funds made available by unpaid leaves of absence to hire ad hoc replacements, and it is virtually impossible to attract applicants of high professional caliber to these temporary and usually part-time appointments.

Here in summary form is a partial account of what the Literature Faculty has been up to in the scholarly way during the past academic year. Articles were accepted by or appeared in the following professional journals: American Film, Ancient Philosophy, Antaeus, Cinema Journal, Diacritics, Kenyon Review, Massachusetts Review, Modern Language Studies, Nineteenth-Century Fiction, Radical Teacher, Renaissance Quarterly, Southwest Review, and Yale Review, among others. Essays or chapters written by our faculty appeared in books published by Beacon Press, New York University Press, Ohio University Press, Praeger, Stanford University Press, University of Chicago Press, and The Book of Knowledge. Fiction or poetry by faculty members appeared in American Poetry Review, Atlantic, Beloit Poetry Journal, California State Poetry Quarterly, Crosscurrents, Dan River Anthology, New Orleans Review, Pennsylvania Review, Yale Review, Yankee, and Wooster Review. Two books were completed: Professor Steven Mullaney's study of the Elizabethan stage has been accepted by the University of Chicago Press and a volume of essays on classical subjects edited by Professor David Halperin is out for consideration at several publishers. Papers by faculty members were given at major conferences held at the following universities: Harvard University, Berkeley, California State at San Diego, University of Southern California at Santa Cruz, Montpellier (France), NYU, University of Pennsylvania, University of West Berlin, Hebrew University of Jerusalem, University of Washington at Seattle, Ohio State University, University of Minnesota at Minneapolis, Columbia University, Michigan State University, University of Iowa, and Illinois State University. Papers were also given at the annual convention of the Modern Language Association. Two plays were produced by Professor A. R. Gurney, Jr.: one, The Perfect Party, has been a critical success in New York City and is still in extended engagement, and another (starring Mary Tyler Moore) is in early try-out at Williamstown. Members of the Literature Faculty were active in editorial or consultational capacities for the National Endowment of the Humanities, the American Council of Learned Societies, the Hubbell Awards Committee, the Selection Board of the Literary Classics of the United States, and for several journals and university presses. Finally, we list the following honors worthy of particular mention. Professor Halperin has filled a position in residence at the National Humanities Center, Professor Stephen Tapscott has been appointed Scholar-in-Residence at the Poetry Center of the 92nd Street Y and Professor John Hildebidle has received the John Gardner Award for shorter fiction, which carries with it the award of publication by the New York State University Press of a volume of his short stories.

We are pleased to record the promotions of Professors Hildebidle and Mullaney to the rank of Associate Professor without tenure and the award to Professor Hildebidle of the Class of 1922 Career Development Professorship.

ALVIN C. KIBEL

Leadership and staffing were primary concerns of the music faculty in 1985-86. This was the final year during which five tenured professors (Harbison, Epstein, Thompson, Bamberger, and Lindgren) each took a one-year turn as section head. Having experienced success with this experiment, we voted--with the Dean's acquiescence--to continue it, and Professor Thompson will begin our second rotation next year. Our year-long search for two new instructors of basic musicianship/music theory subjects resulted in the hiring of Assistant Professor Peter Child, a composer, and Lecturer Pamela Wood Ambush, a singer. Lecturer Ambush will also introduce a survey of Afro-American Music to our curriculum. Two of our current instructors--John Corley, who became our Concert Band director in 1946, and Betsy Burleigh, who became our Choral Lab director in 1983--will be promoted from Affiliated Artist (a rank for those who coach our non-credit performance activities) to part-time Lecturer. Next year, students will for the first time be able to earn credit by supplementing Concert Band performance activities with closely related academic pursuits, which will be assigned by Lecturer Corley. Lecturer Burleigh will primarily teach basic musicianship subjects.

Our enrollment for this year was 1,016 students, which represents a continued increase (16% greater than 1984-85, 21% more than 1983-84). Part of the growth stems from the introduction of new subjects, two of which were taught for the first time this spring: Professor Erdely's 21.623 World Music and Professor Coppock's 21.649 Musicianship for Performers. Subject 21.615 Musical Acoustics, which attracted many students each semester, was taught by a new part-time Lecturer, Christopher Blair, who is an MIT alumnus and the director of both Boston Light Opera and the Metropolitan Symphony. Subject 21.658/59 Advanced Musical Performance, which was introduced by Professor Thompson for especially gifted performers two years ago, will be the prime component in a new variant of our joint major (consisting of music and a science or engineering field), for which two semesters of elective credit will be supplanted by two years of participation in Advanced Music Performance plus a senior recital.

The musical groups that we support, which contain many students in addition to those who register for our subjects, provided the community with many outstanding performances this year. These organizations are the Brass Ensemble, Chamber Music Society, Choral Society, Concert Jazz Band, Festival Jazz Band, Gospel Choir, Logarhythms, Symphony Orchestra, and a Chamber Choir that is a new group created and directed by Senior Lecturer John Oliver. Noteworthy events in their schedules this year included leadership of the Brass Ensemble by Greg Hopkins (replacing Richard Given, who was on tour); leadership of the Symphony Orchestra by Alan Yamamoto (replacing David Epstein, who was on leave); frequent conducting of the Concert Band by two students, Ed Ajhar and Charles Marge; IAP tours by the Concert Band to Florida and by the Gospel Choir to cities ranging from New Haven to Washington, DC; a March tour by the Logarhythms to the West Coast; the spring Kresge concert given by the rapidly growing Gospel Choir; the appearance of the Festival Jazz Ensemble, led for the first time this year by Course XXI alumnus Jamshied Sharifi, in the annual jazz competition at Notre Dame; and the debut concert given by the Chamber Choir in Kresge this spring.

Student composers were encouraged to submit their compositions for the third Hsu Prize competition, sponsored by the Section this spring. Top honors went to Douglas J. Carlson, a member of the Brass Ensemble; and an honorable mention award was given to Eric Ostling, a percussionist and pianist in the Festival Jazz Band.

Visiting performers were, as usual, invited for our Thursday noon Chapel Concert series and for our string quartet series in Kresge. Special events included the October performance in Kresge by the Orchestre de la Suisse Romande, which was nationally broadcast, and a series of three musicological/ethnomusicological presentations in the spring.

This year's faculty concerts included two by the Erdely Duo (Professor Stephen Erdely and his wife Beatrice) and one by Aardvark, a jazz orchestra conducted by Lecturer and trumpeter Mark Harvey (who this spring won a Whiting Fellowship to write a biography of trumpeter Howard McGhee). During IAP, Lecturer Roland Vazquez and Ms. Burleigh joined forces to lead a community orchestra and chorus in a performance of Beethoven's *Ninth Symphony*. In April, they once again assembled their forces for an evening of Schubert, which included a complete performance of *Zie Zwillingbruder* and narration by Associate Provost Samuel Jay Keyser (a trombonist in the Concert Jazz Band).

The lack of an appropriate performance space for chamber concerts, guest lectures, and other events in the Humanities will be remedied sometime in 1987, when a renovation of the vacated Hayden Gallery in Building 14 will be completed.

The professorial staff was, as always, engaged in a wide variety of musical activities. Jeanne Bamberger, who was on leave most of the year, received a grant from the Spencer Foundation, published The Music Logo Sourcebook, completed the 5th edition of The Art of Listening, and began writing The Development of Musical Intelligence. John Buttrick, who was promoted to full professor this year, spent the spring semester in Switzerland and Germany, where he gave chamber concerts, solo recitals, and performance-related seminars. David Epstein, who was on leave most of the year, received a grant from the Alexander von Humboldt Foundation, conducted, taught, and led symposia in Germany and France, and continued work on his book concerning musical time in diverse eras and cultures. Stephen Erdely received a grant from the NEH, continued his work on Yugoslavian epic singers, and completed an article on identity preservation--the product of his fieldwork on oral traditions in the music of Hungarians and Hungarian-Americans. John Harbison served as co-director of the Collage ensemble and as new music adviser for the Los Angeles Philharmonic; he conducted the premiere of his Music for Eighteen Winds at the annual Abramowitz Memorial Concert in Kresge, and he coached rehearsals of various other works, which were performed in Europe as well as the USA. Lowell Lindgren received an NEH grant, read papers at Handel tercentenary celebrations in Europe, Canada, and the USA, published two articles concerning Italian baroque opera, and completed a three-year term as review editor for the Journal of the American Musicological Society. Marcus Thompson served as Coordinator of the Performing Arts at MIT and played many solo concertos and chamber concerts in the USA and Europe. Barry Vercoe continued the New Musical Resources series of concerts in Kresge and made progress on his path-breaking research, which will allow computers to become time-flexible members of musical ensembles.

Our eight Lecturers likewise had a broad array of outside accomplishments, including compositions, performances, directorial positions, invited papers at conferences, and publications. The five-year appointments for both of our Senior Lecturers, John Oliver and Edward Cohen, were renewed this year. Two of our Lecturers, Herb Pomeroy and Melissa Howe, will leave us, after twenty-three and seven years of service, respectively; we wish them much success in their future musical careers.

Under the leadership of Professor Thompson, we have this year begun planning a more cohesive program for MIT's performing arts: dance, drama, and music. We are grateful for the assistance rendered us by many who are outside our Section, most notably by those who served on the Executive Committee for the Performing Arts. We are likewise thankful to those who helped with the forthcoming conversion of the old Hayden Gallery into a performance facility or helped us to identify further spaces at the Institute which might be utilized for rehearsals and performances of our many musical groups. In sum, we have had a very productive year; and, "with a little more help from our friends" in the coming years, we should be able to make significant improvements in the state of the performing arts at MIT.

LOWELL LINDGREN

The Writing Program performs a vital teaching service at the Institute. The Program's curriculum maintains a depth and balance appropriate for the diverse student population. The current undergraduate subjects in expository writing, creative writing, and science and technical writing draw a steady enrollment of students at all levels, advanced and beginning alike. Many subjects satisfy either phase one or phase two of the Institute Writing Requirement. The cooperative writing subjects for both undergraduate and graduate students, within the various engineering departments, have held their enrollments and are expanding to new departments in the School of Science. The summer session short-course, "Communicating Technical Information," continues to be popular with many students from industries throughout the world.

In addition to offering an academic curriculum for the student body, the Program has continued to bring to the larger MIT community distinguished writers and poets who share their ideas about their work and the craft of writing. Among the roster of writers were biographers Justin Kaplan, Michael Scammell, and Cynthia Wolff; the poets were Robert Creeley, Michael S. Harper, Les Murray, and Michael Palmer; the science writers were Jon Franklin and Perri Klass; and the novelists were David Bradley and Gloria Naylor. This year-long series ended with a particularly rewarding presentation — a public reading to a capacity audience at Kresge Auditorium by the Nobel Laureate Isaac Bashevis Singer. The MIT and larger communities continue to appreciate the Program's efforts in this regard.

Several faculty had new books released this year. Bernard Avishai published The Tragedy of Zionism and Joe Haldeman Dealing in Futures; visiting writers Janette Hospital and Fanny Howe published Borderline and Robeson Street, respectively. All releases received critical and high acclaim. Elzbieta Ettinger's Kindergarten, first published in 1970, was reissued this spring in paperback.

Elzbieta Ettinger Chodakowska was promoted from associate to full professor. She will publish a major biography of Rosa Luxemburg this fall.

Kenneth Manning received a substantial grant for a research project on "Blacks in American Medicine, 1860-1980," from the Henry J. Kaiser Family Foundation and the Josiah Macy, Jr. Foundation. The Josiah Macy, Jr. Foundation and the Alfred P. Sloan Foundation both provided planning grants for this project.

The Writing Program received a gift from Institute alumnus Stanley J. Klein to offer a writing prize to MIT undergraduates in science writing. The prize will be offered for the first time during the upcoming year.

Robin Becker, Marilyn Richardson, and Harriet Ritvo will be returning from faculty leaves. Edward Barrett, a professor from the New Jersey Institute of Technology, will be joining the Program as lecturer to help in the cooperative writing subjects in the School of Engineering and with other aspects of phase II of the Writing Requirement. The Pulitzer Prize winning poet Maxine Kumin will join the Program as visiting writer for the coming academic year.

KENNETH MANNING

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## Department of Linguistics and Philosophy

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During the year, we continued to explore ways which will enable us to compete financially for the best students in our two graduate programs. We are grateful to the administration for understanding our needs in this area, and also to our Visiting Committee, under the chairmanship of Mr. Edward Thompson, for citing graduate student support as the most critical problem facing the department. Because of greater flexibility in the expenditure of certain funds, we were able to cover our needs this year, and we shall probably be able to do so in 1986-87; but beginning in 1987-88, we face the possibility of reducing the numbers of new admissions to the programs (numbers which are already small) unless further funding is found. Again, we appreciate the recommendation by the Visiting Committee that lowering the number of students is an untenable option.

### Research: Linguistics

In addition to research in empty categories, theory of government, poetics, agreement phenomena, binary branching, the comparative syntax of adjectives, and phonological problems in Romance languages, there was much research focusing quite particularly on certain languages: Hopi and Papago (Uto-Aztecan languages), Warlpiri (Australian), Winnebago and Navajo. In January, Professors Kenneth Hale and Wayne O'Neil, along with eight other linguists, traveled to the Atlantic coast of Nicaragua, where they offered workshops to over 125 preschool, first- and second-grade teachers and curriculum developers working in the Bilingual-bicultural Education Program in that country. The purpose of the workshops was to assist the Creole, Miskitu, and Sumu educators to realize their capacity to develop language programs and to give them linguistics tools for doing so.

### Research: Philosophy

Philosophical research continued this year in philosophy of mind (with particular attention to problems of mental representation), logic and philosophy of logic (predicate provability logic, the concepts of logical truth and logical consequence), philosophy of science (determinables and natural kinds, the asymmetry of time, problems of scientific change), moral and legal philosophy (privacy in law and ethics, the notion of legal responsibility), and existentialism.

### Publications

Institute Professor Noam Chomsky continues to be the department's most prolific author. His three books published this year are: Knowledge of Language (New York: Praeger), Turning the Tide (Boston: South End Press), and Barriers (Cambridge: MIT Press). Other members of the department published articles and reviews on a wide range of philosophical and linguistic topics and were invited speakers at various conferences and colloquia in this country and overseas.

### Honors and Awards

Professor Judith Jarvis Thomson has been awarded both a National Endowment for the Humanities Fellowship and a Guggenheim Fellowship; she will accept the former for 1986-87 and the latter the following year.

Professor Chomsky was made an Honorary Fellow of the British Psychological Society.

Professor George Boolos has been appointed for a four-year term as a regular member of the National Committee for the International Union for the History and Philosophy of Science.

### Leaves of absence

While on sabbatical leave, Professor Chomsky gave several lectures in this country and abroad. In Madrid, he was honored by, and participated in, an "international symposium on the thought of Noam Chomsky", organized by the journal Teorema and the Logic Department of the Universidad Complutense.

Thomas S. Kuhn, Laurance S. Rockefeller Professor of Philosophy, also on sabbatical leave, was much in demand as a guest speaker/lecturer. Among his activities were: the Keynote Address to the XVIIth International Congress of History of Science at the University of California, Berkeley, and a series of lectures at Japanese universities under the sponsorship of the Japan Society for the Promotion of Science.

Professor Joshua Cohen, under a grant from NEH, continued his research on Rousseau and democracy.

Professor Irving Singer, while on sabbatical for one term, continued work on the third part of his trilogy, The Nature of Love.

### Personnel

It is with great pleasure that we report the promotion to tenure of Professor Cohen, who holds a joint appointment with this department and the Department of Political Science.

It is with regret, however, that we report the resignation of Professor Jerry Fodor, who has held a joint appointment with this department and Psychology for many years. Professor Fodor will take up a position as Distinguished Professor at the City University of New York Graduate School. Professor John Carriero has accepted a position at Harvard. Two other resignations are Professors John Ross and Scott Weinstein.

At the end of my first year as department head, I would like to thank especially Institute Professor Morris Halle for taking over temporarily the chairmanship of the Linguistics section, and I look forward to working with the new chairman, Professor O'Neil.

RICHARD L. CARTWRIGHT

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## Department of Political Science

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A large share of the Department's collective energy has been invested this year in planning and recruitment. The unexpected loss of several senior faculty members in the last two years, combined with the normal exodus of junior faculty for positions elsewhere, has created an unusual opportunity for rethinking our priorities. On the one hand, vacancies have emerged in certain fields where the Department has traditionally been strong and has a distinct comparative advantage. On the other hand, the unusually large turnover presents an occasion to modify our staffing patterns in response both to newly felt needs of the Department and to changing perceptions in the discipline concerning potentially fruitful areas for research. The faculty has been debating these issues, reviewing the current curriculum and structure of fields while confronting the specific choices that arise in recruiting new faculty.

Searches were conducted this year in two areas: defense and arms control, and public policy. The defense and arms control field is one of traditional strength for the Department and the Institute, and we have been seeking to fill the substantial gap created by Professor William W. Kaufmann's retirement in 1984. We are very pleased to have persuaded Dr. Barry Posen, currently at Princeton, to join the Department as Associate Professor with tenure. Professor Posen has written an award-winning book on European military strategy between the world wars and is a leading academic specialist on the use of conventional forces in military strategy. His appointment complements well the expertise of other department members in strategic forces, arms control, and Soviet military policy.

A search in public policy was necessitated by the resignation of Professor Alan A. Altshuler a year ago to become Dean of the Graduate School of Public Administration at New York University, and by Associate Professor Deborah A. Stone's decision this year to accept an endowed chair offered by the Florence Heller Graduate School for Advanced Studies and Social Welfare at Brandeis University. Both senior and junior candidates were considered, and a position was offered to Ms. Ellen M. Immergut, a highly-regarded young sociologist from Harvard specializing on comparative social welfare policies; she will be appointed an assistant professor upon completion of her dissertation.

Our recruitment efforts will continue, since we anticipate having three or four positions to fill in the next two or three years. By national standards, we are a relatively small department (about 27 faculty at full strength), which implies that even some strongly felt needs may be beyond our immediate grasp. We intend to compensate for this in part by placing a particular premium on candidates who can contribute effectively to teaching and research in more than one area of the Department. For the present, we plan also to favor junior over senior appointments, partly for budgetary reasons but more importantly so as to achieve a better-balanced age structure on the faculty. Above all, we intend in general to place greater weight in our searches on the overall excellence and promise of candidates than on their capacity to fill a particular set of Departmental priorities defined in advance. Outstanding political science departments come in many different configurations with regard to field and subject coverage, but there is no substitute for individual excellence. For these reasons, the decision has been made to experiment next year with a broadly-based search procedure oriented toward identifying superior candidates in a wide variety of possible fields and, insofar as possible, choosing among the finalists on the basis of their overall relative merit and suitability for the Department. Under the guidance of the Personnel and Planning Committee chaired by Professor Myron Weiner, the entire faculty will be involved in this broad and aggressive search effort.

Inadequate financial assistance for graduate students remains the Department's greatest weakness relative to other leading departments. We have fewer tuition fellowships and stipends to offer incoming students than our competitors, and we can make fewer and less generous guarantees for support beyond the first year. This puts us at an evident disadvantage in the annual competition for those exceptionally able and interesting students whose presence enlivens the Department while they are with us, and enhances our reputation when they leave. We are grateful for the two additional tuition fellowships the Institute has provided this year, as well as for procedural changes that have allowed greater flexibility in the use of existing resources, but the basic problem can only be resolved by the addition of new funds.

Department members have made their usual vigorous contributions to the scholarly literature. Some of the highlights -- books published and book manuscripts completed -- will stand here as surrogate for a far larger total body of published work. Professor Walter Dean Burnham has prepared a revised edition of his Democracy in the Making, a highly regarded college text on American politics. Professor Nazli Choucri, along with Robert C. North of Stanford University, has completed a book manuscript on Lateral Pressure and International Conflict: The Case of Japan. Associate Professor Russell Neuman's book, The Paradox of Mass Politics: Knowledge and Opinion in the American Electorate, will be issued in August by



the Harvard University Press. Harvard has also published Professor Lucian W. Pye's impressively wide-ranging and stimulating study entitled Asian Power and Politics: The Cultural Dimensions of Authority. Along with three co-authors, Professor Robert I. Rotberg has published South Africa and Its Neighbors: Regional Security and Self-Interest. Associate Professor Richard J. Samuels has completed a major study on Japan, Energy and the Business of the State: Japan in Comparative and Historical Perspective, which will appear in a Cornell University Press series. Basic Books is about to publish Professor Harvey Sapolsky's book on consumer product risks, Consuming Fears: The Politics of Product Risks. Finally, Assistant Professor Charles Stewart III has completed his study of The Politics of Structural Reform: Reforming Budgetary Structure in the House, 1865-1921.

To a greater extent than other social scientists, perhaps, political scientists find themselves pulled in conflicting directions. While their primary responsibilities are teaching and research, and they write by and large for an academic audience, they are also frequently called upon to contribute in one way or another to the debate and resolution of public policy issues. The policy-oriented side of the Department's life can be well exemplified by the following partial roster of the year's public service activities.

Professor Lincoln P. Bloomfield has been engaged in developing a new program whereby the State Department's Center for the Study of Foreign Affairs will organize what is officially termed "diplomatic exercises and simulations." Otherwise known as "political games", these exercises have been organized by Professor Bloomfield in many settings since he first experimented with them at MIT in the 1960s. Professor William E. Griffith has been on leave this year serving as Minister-Counselor for Cultural Affairs to the American Embassy in Bonn. Professor Willard Johnson has contributed to public understanding of South African issues by taking leadership in the Association of Concerned African Scholars and the Free South Africa Movement; he has also served as advisor in reviewing United States development projects for Africa. Professor Michael Lipsky has been serving on a National Academy of Science Committee on the Status of Black Americans. Dr. Louis Menand, Senior Lecturer in American Politics, has been engaged through the American Civil Liberties Union and other organizations in issues involving surveillance, privacy, and national security. Associate Professor Stephen M. Meyer has consulted with various government agencies and been sought out regularly by the national media in his capacity as a specialist on Soviet security studies. Professor George W. Rathjens has, as usual, been in heavy demand as a lecturer and conference participant in this country and abroad on issues of national security and arms control, including the President's Strategic Defense Initiative. Professor Sapolsky, whose interests include both health policy and defense policy, completed this year an evaluation of the use of the diagnosis-related method of payments for hospitals in New Jersey; he is now turning to a major study of the history of the Strategic Defense Initiative. Professor Eugene B. Skolnikoff gave testimony to the House Committee on Science and Technology on "Coordination and Management of International Cooperative Research." Professor Peter A. Smith has worked with the Ford Foundation to develop a project on the future of U.S.-Mexican relations that will involve collaboration between business, government, and academic leaders in both countries over several years.

Some honors and awards received by members of the faculty deserve mention. Professor Suzanne Berger has been on leave for much of the year teaching at the Ecole des Hautes Etudes in Paris in her current capacity as holder of the French-American Foundation Chair in American Civilization. Associate Professor Joshua Cohen was awarded tenure this spring, to the satisfaction of colleagues and students in both of his departments, Political Science and Philosophy. Professor Pye has been elected Vice President of the American Political Science Association, which Professor Weiner currently serves as Secretary.

Finally, I must with deep regret report the death, following heart surgery, of Professor Emeritus Harold R. Isaacs. Professor Isaacs came to MIT in 1953 as a research associate in the newly founded Center for International Studies after a twenty-year career as journalist and author focusing on China and Southeast Asia. He subsequently joined the faculty, contributing his talents and broad experience to our innovative teaching and research program in international communications. While at MIT he wrote eight books whose shared purpose was to explore attitudes and feelings of particular national, racial, or ethnic groups about international issues. Harold Isaacs' intellectual style was that of the tough-minded, probing reporter. The books resulting from his inquiries, however, were given their meaning and spirit above all by the large sense of empathy and compassion he felt for those whose perceptions of the world he sought to understand.

DONALD L.M. BLACKMER

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## Department of Psychology

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The major development of the year is the amalgamation of this department into a new and larger department called Brain and Cognitive Sciences beginning July 1, 1986. The new grouping will encompass disciplines, with appropriate faculty, ranging from neurobiology to cognitive science. It will be centered in Whitaker College and headed by the current Director of Whitaker, Professor Emilio Bizzi. The new and larger department will maintain and extend the activities of the pre-existing groups. Their interactions will vigorously enhance the effort to advance the frontiers of knowledge in both the brain and cognitive sciences and to develop the terra incognita between them. A timely grant of \$5 million from the Fairchild Foundation for support of new faculty and students in computational neuroscience lends impetus to this program. The new department represents an innovative effort to exploit the resources available at MIT in order to further an enterprise of great promise.

### Personnel

An unusual number of changes occurred this year. Institute Professor Walle Nauta retired after serving the department and the Institute for 22 years. In addition to his great distinction as a neuroanatomist, Dr. Nauta has been a renowned teacher and just became the first recipient of the Irving London Teaching Award. Professor Gerald Fodor leaves the Institute after serving both this department and Philosophy and Linguistics for 22 years. Both colleagues will be missed. Two new additions to our faculty have been made -- Mriganka Sur becomes Associate Professor in the area of neuroscience and Ellen Hildreth becomes Fairchild Assistant Professor in the area of computational vision. Professor Alan Hein has spent a year of sabbatical leave in France. Among many other honors received by our faculty, Professor Bizzi was elected to the National Academy of Science, Professor Steven Pinker was awarded the Boyd McCandless Prize for outstanding junior researcher in developmental psychology, and Professor Mary Potter was elected to the Governing Board of the Psychonomic Society. The Irwin Sizer Award for Innovation in Undergraduate Education was awarded to the Committee for the Cognitive Science Major.

### Education

The number of undergraduate majors in the cognitive science program, now in its fourth year, continues to increase linearly while enrollment in our undergraduate courses appears to be increasing exponentially. The only constraint on this increase is resources in the form of faculty time and assistantships available for these teaching efforts. Much of this enrollment remains in traditional psychology courses. At the graduate level the doctorate was granted to six students. Thirteen new students were admitted, a larger than usual class, in recognition of the increased size of the department. The Fairchild grant will help support these additional students.

### Research

The amalgamation of programs will increase the overall research budget but will not lessen the burden of finding continued support for the many projects going on within the department. As the competition for federal funds becomes keener, even highly ranked investigators have difficulties funding their research. As more of the tax dollar goes into the defense establishment, there is increased spillover into research and development. We see a trend toward looking to the military for research support. The desirability of this trend is debatable but the hard facts are irrefutable. The very desirable alternative is, of course, support from non-federal sources which have the foresight to recognize the promise of the new department for making scientific advances with potential application.

### The Future

The amalgamated program contains an increased diversity of subject matter with a correspondingly greater potential for progress. The range of disciplines is considerably expanded as is the number of faculty. Relations among the faculty have always been congenial, rarely competitive, and differences in intellectual content and style have been either respected or tolerated. We should like to see these attitudes continue. It requires mutual acceptance by faculty members and patient and creative leadership by administrators. Given these ingredients we can anticipate a period of unprecedented opportunity for advances in our knowledge of biological intelligence: characterized as the last intellectual frontier.

RICHARD HELD

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## Program in Science, Technology, and Society

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### TEACHING

In Science, Technology, and Society's (STS) undergraduate teaching program, the major news was the continued success of the Integrated Studies Program (ISP). This program offers freshman the opportunity to combine the learning of mathematics and physics with a study of the historical, cultural, and social context in which Western science and technology have developed since the seventeenth century. This is done by having them take their mathematics and physics as a group, with the recitation sections scheduled as two blocks of two hours each and by asking them all to register for an ISP Humanities Distribution subject and one of several seminars taught by STS faculty. ISP was begun last year and attracted a small number of students. This year enrollment was 37, and both students and instructors thought highly of the experience. The enrollment compares favorably with the experience of Concourse and Experimental Study Group at the corresponding stages of their history.

The first two students who completed a double degree program of Engineering and STS were graduated: Atsushi Akera and Ronald Reuss. Mr. Akera's degree was in Electrical Engineering and Computer Science (EECS) and Humanities (STS) with a thesis on the Ethnography of an Athena Terminal Room; Mr. Reuss also received a degree in EECS and Humanities (STS) with a thesis on Computer-aided Reading.

Enrollments in the undergraduate courses showed a modest increase.

The STS faculty continued to work with graduate students and supported them with fellowships and/or study space. These included 13 admitted in Political Science and one in Urban Studies and Planning. Colleen Dunlavy, though not yet finished with her thesis, received a tenure track appointment as an assistant professor at the University of Wisconsin, Madison to teach the History of Technology in the History Department.

### RESEARCH AND HONORS

Professor Loren Graham spent half time on leave as Visiting Professor in the History of Science at Harvard. Professor Graham also launched and funded a three year project on the Humanistic Dimensions of Science and Technology in the Soviet Union. Most of the \$300,000 in support came from the National Endowment for the Humanities. The project, based in STS, involves scholars from other universities and will result in a book of essays. Professor Graham received the honorary degree of Doctor of Letters from Purdue University of which he is an alumnus. Professor Kenneth Keniston was on leave for the Spring 1986 term as Visiting Professor at the Sorbonne. Professor Sherry Turkle's book The Second Self: Computers and the Human Spirit received the Melcher Book Award of the Unitarian Universalist Association for a significant contribution to religious liberalism.

### THE EXXON FELLOWSHIP PROGRAM

This academic year saw the sixth and final year of the Exxon postdoctoral fellowship program which supports scholars in the history and social study of science and technology. The two Exxon Fellows this year were Thomas Carroll, Assistant Professor of History in the Department of Science and Technology Studies at Rensselaer Polytechnic Institute, and Kathleen Archibald, Professor at the Graduate School of Public Affairs at the University of Colorado, Denver. Professor Carroll continued his work on the history of chemistry in American universities which will result in a book. Part of the year's work will appear in three articles in the next year. Professor Archibald is writing a book on the RAND Corporation, focusing on its contribution to the development of analytical techniques for public policy analysis and advice-giving.

In the six years of its existence, the Exxon program has brought to MIT an interesting group of scholars in the history and sociology of science and technology who have added much to the intellectual life of the Program, including significant interactions with graduate students as well as faculty. In the nearly unanimous testimony of the 22 fellows, the time the fellowship affords and the stimulus of the MIT environment have contributed substantially to the progress and success of their work.

### THE MELLON FELLOWSHIP PROGRAM

The Mellon Fellowship Program supports researchers in engineering and science disciplines who wish to spend a year examining the problems of the social interactions of science and technology. The program supported two fellows this year: Peter Taylor, who had just completed a Ph.D. at the Museum of Comparative Zoology at Harvard, and Dennis Sebian of the Boston Water and Sewer Commission. Dr. Taylor worked on the social implications of using quantitative models to study complex ecological systems. His program included both a discussion of the question in general terms and a historical case study of the rise of systems

ecology in the period 1962-70 when the United States entered the International Biological Program. Mr. Sebian, who held the fellowship on a part-time basis, moved toward completing his book on Arthur Hazen and the creation of the Boston water system which he has worked on with support from the program for the last several years.

#### THE VANNEVAR BUSH FELLOWSHIP PROGRAM

The Vannevar Bush Program in the Public Understanding of Science and Technology completed its third year. The eight American science journalists who held Bush Fellowships this year were: David Ansley (San Jose Mercury News), Erich Hoyt (author/freelance journalist), Karen Klinger (San Jose Mercury News), Seth Shulman (Science for the People), Dick Thompson (Time), Michael Unger (Newsday), David Wheeler (Valley News), Robert Zalisk (independent producer/freelance writer). The program continues to be highly successful as indicated by the increasing maturity of the fellows who come and the increasing recruitment from larger journals this year; Time and Newsday were represented for the first time in the list of employers.

#### VISITING SCHOLARS

Evelyn Keller, Professor of Mathematics and Humanities at Northeastern University, spent the spring term of last academic year and the fall term of this year as a visiting professor in STS and the Women's Studies Program as the holder of a National Science Foundation Visiting Professorship for Women in Science. She continued in the spring term as visiting scholar. In addition, the following individuals spent the whole or part of the academic year as visiting scholars working with the Program faculty and participating in its internal life: Mr. Erik Albaek (Institute of Political Science, University of Aarhus, Denmark), Dr. Stephanie Bird (1982-83 Mellon Fellow in STS spent the year completing her project funded by an Ethics and Values in Science and Technology (EVIST) award through the National Science Foundation; this was a joint appointment with STS and the Center for Technology, Policy, and Industrial Development), Dr. Joan Bromberg (Director, The Laser History Project, Woburn, Massachusetts; this was a joint appointment with STS and EECS), Dr. Alberto Cambrosio (Social Sciences and Humanities Research Council of Canada Postdoctoral Fellow, Department of Sociology, University of Montreal), Professor Kakugyo Chiku (Kanazawa Institute of Technology, Japan; this was a joint appointment with STS and the Center for International Studies), Dr. Henry Cole (Geophysical Institute, University of Alaska), Mrs. Jill Conway (former President, Smith College), Professor Elizabeth Hagen (University of Economics, Vienna), Professor Gregory Jackson (Harvard Graduate School of Education), Professor Camille Legendre (Department of Sociology, University of Montreal), Dr. Ettore Santi (General Director, Center of Social and Union Studies, Rome), Mr. Russell Schweickart (California Energy Commission), Professor Michael Smith (Department of History, Williams College).

#### OTHER ACTIVITIES

Professor Carl Kaysen continued his activity in connection with the 13 part television documentary entitled The Nuclear Age now in production by WGBH. He serves as Chairman of the Editorial Advisory Board, and together with Professors Paul Doty, Harvard, and Jack Ruina, MIT, is responsible for the intellectual substance of the program. Professor Leon Trilling (Department of Aeronautics and Astronautics and STS) serves as President of the Council for Understanding Technology in Human Affairs (CUTHA), a group of engineering and liberal arts faculty which organizes workshops for liberal arts faculties which helps them to include technology oriented materials in their courses. The work has been funded by Exxon and Sloan Foundations and AT&T.

CARL KAYSEN

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## Center for International Studies

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The past year has begun an important period of transition for the Center for International Studies. Professor Eugene B. Skolnikoff (Department of Political Science), who has been Director since 1972, has announced his intention to return to full time teaching in July 1988. A search for a new Director and exploration of possible affiliations with other policy research centers at MIT has been underway and will continue in the coming year.

Work on issues of arms control and defense policy continue to be a major part of the Center's program. Under the direction of Professor Jack Ruina (Department of Electrical Engineering and Computer Science), the Center's Arms Control and Defense Policy Program continued to support graduate students, principally from the Department of Political Science, whose graduate study and thesis research are focused in the arms control and defense policy field. Faculty associated with the program, along with Professor Ruina, are: Professors Stephen Meyer, Steven Miller, George Rathjens, and Harvey Sapolsky (all of the Department of Political Science). An important expansion of the faculty for the future took place in the spring of 1986 when, after an extensive search, Professor Barry Posen was selected to join the Political Science faculty concentrating in this field; Professor Posen's expertise in conventional weapons issues and in the defense policy and arms control field in general will add depth to the program in future years.

The faculty, research assistants, and postdoctoral fellows and research associates at the Center are engaged in a number of research efforts. During the past year, research subjects included: new weapons technology and its impact on U.S.-Soviet strategic relations, the navy in the nuclear age, the analyses underlying the "nuclear winter" hypotheses, public opinion and the evolution of arms control policy, domestic politics and defense-arms control decisions, and a number of questions relating to the Strategic Defense Initiative. A major component of this research has concentrated on Soviet weapons development, acquisition, and defense and arms control decision making. Working with the program faculty on these undertakings have been the following members of the Center staff: Matthew Bunn (Research Fellow), William Durch (Research Associate), Charles Glaser (Research Associate), Morton Halperin (Visiting Scholar), Bernard Kramer (University of Massachusetts and Visiting Scholar), Herbert Lin (Postdoctoral Fellow), and Charles Whitechurch (Visiting Air Force Associate).

The members of the program, through writing, lecturing, testimony before Congressional Committees, service in advisory capacities to various government agencies, and participation in public interest groups have continued to share the results of their work with the broader community. A series of seminars at MIT serve also as communication links between the program and the MIT and broader community of persons concerned with this policy area. Two special programs in the past year should be mentioned. Professor Ruina and other program staff worked with Professor Louis Smullin (Department of Electrical Engineering and Computer Science), in organizing a one-day symposium in November 1985 on the Strategic Defense Initiative; the symposium was held at the initiative and under the auspices of Provost John Deutch. In June 1986, the program held the fourth two week workshop on nuclear weapons and arms control for faculty from American and West European liberal arts colleges who offer courses in their home colleges that deal with these issues; the workshop was offered jointly with the Center for Science and International Affairs of Harvard University.

The Center's work on arms control and defense policy receives substantial support from the Institute, which has created a Fund for International Security and Arms Control for this purpose. In addition, the Hewlett Foundation provides core program support; the Carnegie Corporation has made a major grant to support research; the Ford Foundation provides funds for students; and the Defense Advanced Research Projects Agency and the Office of the Secretary of Defense support work on Soviet defense policy. The Sloan Foundation has continued to fund the summer workshops and the Levinson Foundation supported the nuclear winter study.

Closely related to this program has been an initiative made possible by a grant to the Institute by the John D. and Catherine T. MacArthur Foundation to expand the numbers of MIT faculty and students working on arms control and international security issues. The Provost appointed an Institute faculty committee under the co-chairmanship of Professors Skolnikoff and Carl Kaysen (Director, Program for Science, Technology and Society), to distribute the award at the Institute. Awards have been made for faculty and student research under the direction of the following: Professors Hayward Alker, Jr. (Department of Political Science), Aron Bernstein (Department of Physics), Edwin Diamond (Department of Political Science), Thomas Jordan (Department of Earth, Atmospheric, and Planetary Sciences), Philip Khoury (History Faculty), Jean Louis (Department of Aeronautics and Astronautics), Harvey Sapolsky (Department of Political Science), Thomas Sheridan (Department of Mechanical Engineering), Lawrence Susskind (Department of Urban Studies and Planning), and Lance Taylor (Department of Economics), and Eric Chivian, MD (MIT Medical Department) and Marvin Miller (Senior Research Scientist, Department of Nuclear Engineering).

Funds have also been provided to the MIT Libraries to strengthen their holdings of materials related to arms control and international security and to sponsor increased opportunities for communication among the members of the MIT community who share a concern for these issues.

Another major cluster of Center program activities concern Japanese science and technology. This effort is directed by Professors Richard Samuels (Department of Political Science) and Eleanor Westney (Sloan School of Management). The objective of the program is to redress the asymmetry in U.S.-Japanese relations by making possible a greater flow of Americans to Japan, and thus also improve communication between American and Japanese scientists and engineers. In addition, the Program facilitates joint or collaborative research, promotes travel and other contacts, and provides American scientists and engineers with improved access to scientific and technological developments in Japan through improved circulation of Japanese published reports and studies and through training in Japanese language. A substantial number of MIT students and recent graduates have been placed as interns in Japanese industries and laboratories; students selected for this intern program take intensive Japanese language courses, as well as courses on Japanese history and culture in order that their intern year will be most productive for them. The intern program is funded by the Starr Foundation; support for the program as a whole has been provided by the Institute and by a consortium of American industries: AMF Industries, Eastman Kodak, General Electric, International Business Machines, Motorola, Proctor and Gamble, and Teradyne.

The policy aspects of migration - how states regulate the international or internal movements of peoples and how such movements affect domestic and international politics - were the subjects of work carried out by Professors Nazli Choucri and Myron Weiner (both of the Department of Political Science). With support from the Ford Foundation, Professor Weiner studied in India and Professor Choucri in Egypt. Professors Weiner and Oded Stark (Center for Population Studies, Harvard) cosponsored seminars on migration during the past year; that program together with the Hebrew University of Jerusalem held a conference at the Center in April on irridentism.

A grant from the Ford Foundation also supported a special program of sessions of the Joint MIT-Harvard Seminar on Political Development (JOSPOD) during its twentieth anniversary year. Under the joint chairmanship of Professors Weiner and Samuel Huntington (Center for International Affairs, Harvard), JOSPOD commissioned papers assessing how the field of political development had changed over those two decades; the papers will be published by Little, Brown in early 1987.

The Center's long-standing interest in food and nutrition policy in development has been strengthened by the move into the Center's headquarters of the International Food and Nutrition Program (IFNP) headed by Nevin Scrimshaw (MIT Institute Professor). Professor Scrimshaw spent part of the past year in Tokyo as Director of the Development Studies Division of the United Nations University (UNU). The Center also hosted this past year Cristina Cacchiamali (University of Sao Paulo, Brazil) who was spending a year with IFNP as a UNU Fellow. IFNP is engaged in research and publication of its own work and of studies sponsored by UNU.

Professor Willard Johnson (Department of Political Science) was engaged in collaborative research on national and cross-national news coverage in Africa with two African scholars - Professors Hughes Kone and Faustin Yao (both from the University of Abidjan, Ivory Coast). This program was supported by a subcontract from Boston University as part of a program of studies of the African-American Issues Center funded by the United States Information Agency. Additional funding has been provided by the Ford Foundation to continue this collaborative MIT-African program in the coming year. More generally in the field of communications policy, the Center serves as the base for the Communications Policy Career Development Chair. This chair supports Professor Russell Neuman (Department of Political Science) and Charles Jonscher (Sloan School of Management).

Developments in the contemporary Middle East were the focus of a series of Bustani lectures organized by Professor Khoury. Internationally recognized scholars were brought to MIT under this program, which was made possible by the Emile Bustani Foundation. The lectures, which have drawn large audiences from the Cambridge academic community, will continue in the coming year.

Professor Lance Taylor (Department of Economics) continued several programs at the Center. With Ford Foundation support, Professor Taylor is studying the status of poor countries in the world economy from a structuralist perspective. The objective is to combine structuralist theory with empirical observation. Professor Taylor also continues as editor of the Journal of Development Economics.

International energy policy issues continued to be the focus of work supported by the Endowment created at MIT by the Ministry of Foreign Affairs of Japan. Mr. Tatsuo Oyama of Saitama University spent the past year at MIT under the joint sponsorship of the Center and the Energy Lab, working on international energy policy issues. Professor Samuels completed a comparative study of energy policy in Japan and Italy. His book, which has aroused much excitement in manuscript form, will be published next year. Also funded in part under this program and in part by the MIT Provost has been Thomas Neff (Principal Research Scientist, Center for International Studies).

The Director of the Center, Professor Sklonikoff developed over the year a plan for a three year study of the interaction of science and technology and the international system. He plans in that study to examine some of the significant underlying relationships that are poorly understood because of the typical focus on specific policy issues. It will be carried out partially in cooperation with the Council on Foreign Relations in its later stages.

Professor Suzanne Berger (Department of Political Science) in collaboration with Mitzi Wertheim (International Business Machines, Federal Systems Division) and Jake Stewart (United States Navy, Director of Planning and Assessment, Office of the Secretary of Defense) has developed a unique program designed to increase awareness of how major world events look from different cultural and ideological perspectives. Members of the United States Government and industry selected because of their potential for future leadership positions will participate in a series of sessions to be held in the Washington area starting in the fall of 1986. Funds to support the program have been received from the Carnegie Corporation, Sloan Foundation, Rockefeller Foundation, MacArthur Foundation, and a number of industries: American Telephone and Telegraph International, Boeing Company, Booz-Allen and Hamilton Inc., Gould Inc., Grumman Corporation, Honeywell Corporation, International Business Machines, and Mitre Corporation.

As in past years, the Center has continued to serve as the MIT base for the joint MIT-Harvard Women in International Development Program. The Center has also offered the MIT and Cambridge academic communities an extensive program of seminars and lectures on international topics and brings to the Institute scholars from foreign universities engaged in work related to our program. During the past year, these included scholars from Brazil, Jordan, India, Japan, Italy, Australia, Peru, and Israel. In addition to support from MIT and from its projects, the Center has been supported by a grant from the Exxon Educational Foundation.

EUGENE B. SKOLNIKOFF

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## Center for Materials Research in Archaeology and Ethnology

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The 1985-86 academic year was the ninth year of operation for the Center for Materials Research in Archaeology and Ethnology (CMRAE). Activities focused in three areas: graduate education of students from the seven participating universities; doctoral research among students from both Center-affiliated and non-Center universities; and the offering of the fifth month-long Summer Institute course.

The Center received a major grant of equipment from the Hewlett-Packard Foundation, enabling CMRAE to establish a computation facility as another in its network of research laboratories. Whereas the intention is to use the facility for primary research in the field of materials and archaeology, the computers will greatly facilitate instruction in the Center's graduate subject on mathematics and computers in archaeological data analysis. The facility made possible our offering of the June 1986 Summer Institute on Computers and Archaeology.

Another important grant was awarded CMRAE by the Anthropology Program of the National Science Foundation. The award supports the final stages of a research project begun several years ago by Professor Suzanne De Atley (MIT, Anthropology/Archaeology) which will provide the archaeological profession with an atlas of microstructures of low-fired ceramic materials studied petrographically and tested at the Center. The atlas constitutes the first set of such reference materials available to archaeologists, geologists, and ceramists.

In 1984 the Center entered into a formal agreement with the Banco Central del Ecuador which involves both institutions in a long range program of research into the origins and development of the mining and metallurgical technologies of Ecuador in the preColumbian era. As part of its responsibility in this endeavor, CMRAE helped design and install a research laboratory at the Museo Antropológico in Guayaquil which was the site of an intensive course on El Examen Metalúrgico de Artefactos Arqueológicos (the metallurgical examination of archaeological artifacts) taught by Professor Heather Lechtman, CMRAE director (MIT, Anthropology/Archaeology), in January 1986. The 23 participants, all from Ecuador, included archaeologists, chemists, metallurgists, and museum personnel. Other follow-up courses are being planned as the sequel to this successful first initiative.

The subject of the Center's year-long graduate offering was Materials in Ancient Societies: Lithics taught by Professor Barbara Luedtke (University of Massachusetts, Boston). In addition, five graduate students at the Center, one from the University of California at Santa Barbara, three from Boston University, and one from Brandeis University engaged in full-time research towards the doctoral degree. Of the students supervised by Professor Lechtman, one is studying the prehistoric development of copper metallurgy in west Mexico and its relation to Andean metallurgies. The four other students are supervised by Professor De Atley. Their dissertation research is diverse in scope, including: the ceramic materials fundamental to iron smelting technologies in east Africa during the iron age; standardization and control of ceramic production in the ancient Mexican capital of Teotihuacán; analysis of the ceramic production of Early Neolithic societies of southern France, as they moved from hunting and gathering to primarily agricultural subsistence economies; the technology of Proto-historic pottery in northwest Iberia. All five students carry out their laboratory analyses and experiments in the CMRAE Graduate Laboratory.

The Center established a Summer Institute in 1981-82, conceived as a mechanism through which scholars at non-Center institutions could benefit from the highly specialized and often unavailable education in laboratory-analytical skills in which the Center is expert. The aim is to provide individuals across the nation in such professions as anthropology, archaeology, the histories of science and art, and the conservation of archaeological and art objects with intense exposure to the theory and laboratory methods of the materials science of ancient and art historical materials. The Summer Institute format consists of a one-month intensive lecture and laboratory subject organized around a specific class of materials. The first course, Materials in Ancient Societies: Metals, was offered during June 1982. The second course, Biological Material from Archaeological Sites: Fauna, was funded by a grant from the Alfred P. Sloan Foundation and was offered in June 1983. Funding for the third course, Materials in Ancient Societies: Ceramics, offered in June 1984, was supplied in large part by donations from the ceramics industry. The June 1985 Summer Institute was organized around the subject of Prehistoric Agriculture. And in June 1986 Professor George L. Cowgill (Brandeis University) and Dr. Edward V. Sayre (Smithsonian Institution) offered Computers in Archaeology: Multivariate Methods in Archaeological Description and Analysis as the Center's Summer Institute subject. The course was taught with the new Hewlett-Packard equipment awarded CMRAE this year.

HEATHER LECHTMAN



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## Women's Studies

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The past year marked the second full year of operation for MIT's Program in Women's Studies. Our curricular offerings expanded, and the number of students enrolled in courses and declaring themselves as majors and concentrators is growing. Women's Studies began to develop a serious following among students -- mostly women, but including some men -- who clearly found here an environment that fosters a sense of community, and an academic base for wide-ranging intellectual curiosity. We continued to forge links with other programs and departments in the Boston area. We hosted a number of events and speakers that were well attended and widely appreciated by a broad MIT community.

### CURRICULUM

In 1985-86, Women's Studies offered 15 courses, enrolling some 250 students. The most popular were: "American Women's History", with an enrollment of 37, and "Psychology of Gender", with 70 undergraduate and five graduate students. "Special Topics in Women's Studies" was instituted during second semester to meet growing student interest in doing independent work of an interdisciplinary nature with an emphasis on women. Two students took advantage of the new opportunity. Working under the direction of Women's Studies faculty, one worked on an analysis of the paradox of Simone de Beauvoir's feminist theory and the portrayal of women in her fiction; the other completed a study (which is being deposited in the archives) of MIT undergraduate attitudes towards gender.

New courses to be offered next year include: "Contemporary Issues in Women's Studies," "Virgin, Harlot, Hysteric: Visual Imagery of Women in Nineteenth-Century Culture," and "Reproductive Biology". It is significant that these last two new courses do not come from the School of Humanities and Social Sciences (they are from "Art and Architecture" and "Science" respectively). We believe that Women's Studies has the potential for being an energizing force within the School of Humanities & Social Sciences, with the basis to forge stable links with the rest of the Institute.

### STUDENTS

Women's Studies has to date 19 concentrators, five declared majors, and two students who have demonstrated a strong interest in majoring. These figures indicate a new locus of strength within the Humanities division. Two of our five majors were Burchard scholars, an indication of the commitment and ability to be found among Women's Studies students.

Several students completed UROP projects in the course of the year, supervised by the Director. One student from Wellesley assisted with conference plans and bibliographic compilation on women and reproductive technologies. Another helped to compile articles for a bibliography for a special issue on "Women and Computers" which Women's Studies is editing for Signs. A third completed a bibliography on women and mathematics that makes an important contribution to the growing literature on gender and science.

Director Ruth Perry worked with two graduate students on their research. She also served as a thesis reader for a Course XXI major whose subject was Black women writers.

### RESOURCES

The resources of the Women's Studies program, which include a reading room and non-circulating subject files maintained in the Women's Studies office, were heavily used in the past year.

The program continues to add to the holdings of the Women's Studies Resource Room, which currently numbers some 1100 books and 40 journal titles. The two extant bibliographies compiled by the program, on "Gender and Science" and "Women and Reproductive Technologies" are frequently requested. We can now add "Women and Mathematics" to that list. The papers from two of our conferences are to be published in two major journals: the set on reproductive technologies will be forthcoming in a special supplement to Women and Health, and the collection on women and computers will be published as a special issue of Signs.

### PROGRAMS AND SPECIAL EVENTS

Once again, Women's Studies offered a number of programs to MIT and the public. The "Symposium on Women and Pornography", co-sponsored by Harvard's Committee on Women's Studies, drew some 350 people to two days of presentations on this heated issue. A three-part series, "Freedom, Fiction, and Family: Black Women Today" brought African National Congress member Nomazizi Sokudela, writer Toni Cade Bambara, and psychologist Helen Boulware Moore to MIT. During Independent Activities Period (IAP), five faculty gave lively presentations in a series on "The New Scholarship on Women: Its Impact on Five Disciplines." The program also co-sponsored a reading by noted poet Carol Oles.

Women's Studies held an open house and sponsored a slide show on South African women, "Forget Not Our Sisters," during International Women's Week in March. A conference on "Women and Reproductive Technologies," co-sponsored by the Technology and Culture Seminar, featured a number of professionals, scholars, and lay people who spoke to a diverse audience concerning the issues involved in these technologies. At the invitation of the American Association for the Advancement of Science, Women's Studies co-sponsored a regional meeting of women interested in issues of gender and science, in preparation for the international Girls and Science and Technology (GASAT) meeting to be held in 1987. Finally, an impromptu session with Italian feminist and comedienne Franca Rame, organized with the Drama Shop, provided a capacity audience a rare opportunity to discuss feminism in an international context.

#### PUBLICATIONS

Several Women's Studies faculty members published books in the past year: Susan Carey, Conceptual Change in Childhood (Bradford Books); Ruth Perry, The Celebrated Mary Astell (University of Chicago Press); Anne Wagner, Jean-Baptiste Carpeaux: Sculptor of the Second Empire (Yale University Press).

Articles about the program and Women's Studies faculty appeared in The Boston Globe, The New York Times, Tech Talk, and The Wall Street Journal. An article on gender and science, based on the Times piece, appeared in several West Coast newspapers.

In addition to publicity for our own programs, the program again published Women's Studies Around Boston, a comprehensive listing of events in the area sent to over 2000 people.

RUTH PERRY

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# Sloan School of Management

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The principal major activities of the Sloan School continue to focus on research dealing with important management issues and on the education of both practicing and potential management professionals and of the educators of the next generation of management professionals and researchers.

The following sections report on the School's teaching programs and research during the past year and on the broad array of related professional activities in which the School's faculty and staff have engaged in that same period.

Our undergraduate program, but principally our master's program and executive education programs, are our principal opportunities for affecting the quality and practice of management, not only in this country but in others, through the dissemination of our own and many others' ideas impinging on that practice.

Our doctoral program is aimed essentially at the training of future educators of management professionals and at training these persons to engage in the serious research which must underlie any successful efforts at professional education.

Our research activities have continued to seek to create and replenish intellectual capital as the basis for understanding the resolution of important management issues, not just in relation to today's headline perspectives but geared for the longer term and thrust.

All of these activities continue to merit the high national and international repute of the School's programs and research.

All of us have also continued to regard ourselves as extraordinarily fortunate in having the opportunity to work with persons throughout MIT who have both understood and who are sympathetic to the School's efforts in continuing to press for the attainment of a clear leadership role in addressing some of the complex managerial problems of our times and of the future.

The School's Annual Report published each year describes in more detail an update on the School's progress in our teaching and research programs and in our other activities. This report provides a somewhat less extensive summary of the School's annual activities during the 1985-86 year.

## TEACHING PROGRAMS

### Undergraduate Program

This academic year was the second for the Sloan School's new undergraduate program leading to the SB degree in Management Science. The 32 seniors who graduated during the year were the final class to receive the SB degree in Management. Of these, 21 were from the (former) Management Science program, two from Behavioral Science, one from Dynamics of Management Systems, and eight from the following approved special programs: Finance (three), Information Systems (two), Organizational Studies, Marketing, and International Management.

Three of our graduates also received bachelor's degrees from the Department of Electrical Engineering and Computer Science, and three graduates simultaneously received the SM degree in Management. Two of our graduates had previously received bachelor's degrees from MIT, one from Electrical Engineering and Computer Science, and one from Mathematics.

Next fall, all of our undergraduates will be following the new Management Science curriculum, which was designed to match more closely the strengths and needs of MIT undergraduates. As can be seen from Figures 1 and 2, the program change has been accompanied by a significant increase in undergraduate enrollment, which this spring totaled 103. (This total does not include 16 students who were enrolled in Management Science for a second SB degree, but who began, and are continuing, in another department.) Of these 103, 36 were sophomores, 41 were juniors, and 27 were seniors.

The new curriculum comprises a core of subjects relating to quantitative analysis and management science, together with a more specialized set of subjects selected from the following options: Information Systems, Operations Research, Marketing Research, and Behavioral Science. Other special options are possible with specific approval of the Undergraduate Office. Of the students who have already declared their option, half have chosen Information Systems. The complete tally is as follows.

#### Regular Options

Information Systems	23
Operations Research	5
Marketing Research	2
Behavioral Science	4

#### Special Options

Finance	10
Systems Dynamics	1
Corporate Strategy	1

Total Declared 46

Because of the strong interest in Finance as a special option, the Undergraduate Program Committee will next year consider the possibility of making it a regular option.

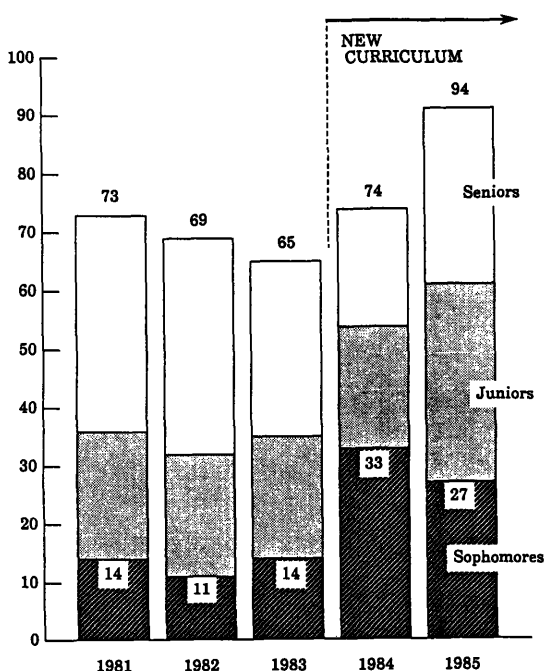


Figure 1

Fall enrollments, by class:  
1981 through 1985

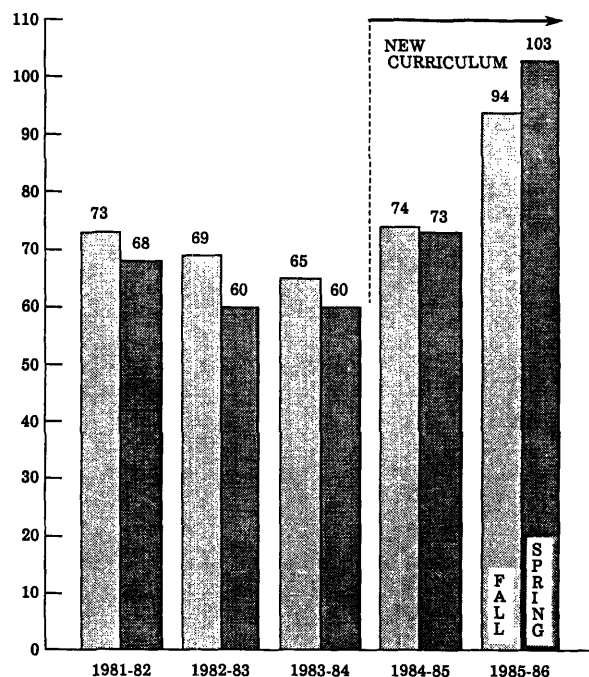


Figure 2

Total enrollments, by term:  
1981-82 through 1985-86

As shown in Figure 3, a substantial--and steadily growing--number of students from other MIT degree programs are enrolled in our undergraduate subjects. During the year there were 542 such enrollments, representing the classroom equivalent of 60 additional full-time undergraduates. (This figure assumes that a full-time student would take 48 units of undergraduate Sloan School subjects each term. A realistic full-time undergraduate load would contain a substantial number of subjects taught elsewhere. Thus, the full-time-equivalent figure is substantially understated.)

Faculty participation in MIT's Independent Activities Period (IAP) in January also has been increasing steadily for the past several years. This year 31 percent of the Sloan School faculty participated, just a bit higher than the Institute average (30 percent). As shown in Figure 4, Sloan faculty participation has almost tripled since 1983. The number of scheduled events rose from about 20 last year to 32 this IAP. Once again, our most popular series was "A Brief Introduction to Management," which drew a total of over 250 attendees. The speakers in this series were Professors William F. Pounds, Stewart C. Myers, Lotte Bailyn, and Phyllis A. Wallace, and Drs. John F. Rockart and JoAnne Yates.

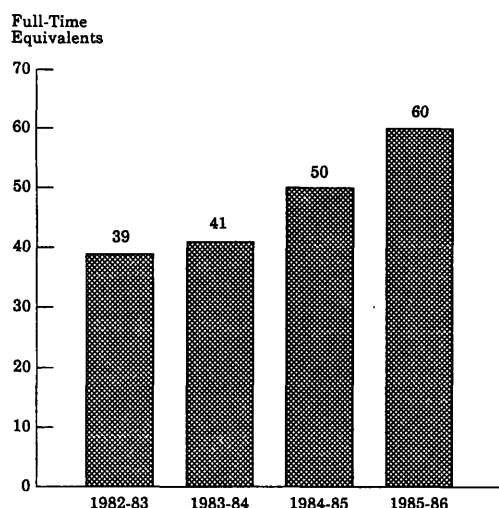


Figure 3  
MIT Students in Other Degree  
Programs Enrolled in Sloan School  
Undergraduate Subjects:  
1982-83 through 1985-86

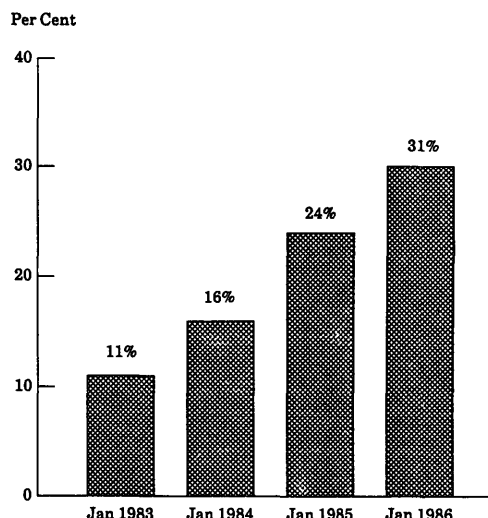


Figure 4  
Sloan School Faculty  
Participation in MIT's  
Independent Activities Period  
1983 through 1986

The Undergraduate Management Game was offered during IAP for the fifth time. It now carries three units of academic credit (pass/fail). Thirty-five students participated, 15 of whom were Sloan School undergraduates.

Ellen L. Spero received the Sloan School of Management Senior Award this year; and Grace Ueng, '87, received, in national competition, a State Farm Foundation Exceptional Student Fellowship.

Increased enrollment required enlarging the Undergraduate Program Committee to provide more faculty advising. Professors Robert M. Freund, Thomas W. Malone, and James B. Orlin joined Professors Thomas J. Allen, Steven C. Graves, M. Anthony Wong, Drs. Stan N. Finkelstein, Jeffrey A. Meldman, Peter M. Senge, and Esther Merrill as undergraduate advisors. Professor Leigh McAlister served as the Sloan School's coordinator for MIT's Undergraduate Research Opportunities Program (UROP). The undergraduate program was chaired by Dr. Meldman and coordinated by Ms. Merrill.

#### Master's Program

The "new" master's core curriculum, which was adopted in November 1984, was implemented during the 1985-86 academic year. While it includes a larger number of disciplines and applications than the previous core, its size--relative to the total master's program--has been kept constant by the incorporation of several six-unit subjects into the core program. Several master's program subcommittees were established to plan for, monitor, and assess the revised core during its first year of operation, including the "Core Coordination and Subject Design Committee," the "Integrative Experience Committee," the "Orientation Program Committee," and the "Scheduling Committee." In addition, a "Student Committee on the Academic Program" was established to provide for maximal student assessment of the "new" core. Although some problems remain to be worked out, in general the revised core has been successful in achieving the goals the faculty established for it in 1984. The "new" core will continue to be evaluated with an eye towards possible future refinements.

The Distinguished Speakers Series presented a diverse and stimulating season. The audiences overflowed Bowen Hall and were able to watch from the Schell Room, via closed-circuit television coverage. This year's speakers, who were chosen and hosted by a board of master's students, were John M. Hennessy, Chairman and Group Chief Executive, Financiere Credit Suisse - First Boston; Mitchell D. Kapor, Chairman and Chief Executive Officer, Lotus Development Corporation; T. Boone Pickens, Chairman and President, Mesa Petroleum Company; Charles L. Brown, Chairman of the Board, AT&T; and Roberto C. Goizueta, Chairman, Board of Directors, and Chief Executive Officer, The Coca-Cola Company.

First-year master's students Elizabeth S. Sooho and Julie A. Tremblay were awarded Digital Equipment Corporation scholarships for outstanding academic performance. This scholarship program was established to encourage women to pursue management careers in the field of high technology.

Seven second-year master's students were awarded scholarships in recognition of academic excellence and professional promise. Paul Maguire and Dennis G. Pratt were named the 1985-86 Martin Trust Scholars, an honor made possible by Sloan graduate Martin Trust. Alexander Proudfoot - Howard J. Samuels Memorial Fellowships were bestowed on Stephen E. Leichtman and Edward A. Stabler. These awards are given annually by the Alexander Proudfoot Company in honor of Mr. Samuels, a former Proudfoot director and longtime friend of MIT. The Henry B. du Pont Scholarship, established by the Crestlea Foundation with a gift from the late Henry B. du Pont, was awarded to Alain H. Boutboul. Frances W. Wong was named Henry Ford III Scholar for 1985-86; the Ford Motor Company Fund established this annual award in 1978. Excellence by a second-year student in the field of accounting is the criterion for receiving the Thomas M. Hill Prize, which was established by the late Professor Hill's friends and colleagues to honor his memory and his 30 years of distinguished service to the Sloan School. This year's prize winner was Simon J. Dyer.

E. Pennell Brooks, first Dean of the Sloan School, established the Brooks Prize to honor the author of the best master's thesis. Sloan Fellows James G. Cosgrove and Ubiratan N. Guzzi were the winners for the 1984-85 academic year with their co-authored thesis, entitled "Risk Free to Risk Taking: Developing the Renaissance Manager." Professor Phyllis A. Wallace served as their thesis supervisor. Marco Villa received honorable mention for his thesis "A Marketing Model for a Software Firm." His thesis supervisor was Professor John D.C. Little. David S. Handmaker and Charles R. Marge were named Seley Scholars, annual awards established by the late Louis E. Seley and Mrs. Seley.

The number of applications for admission increased again this year. We also experienced an increase in the percentage of admitted applicants choosing to matriculate, which resulted in an all-time-high class size of 215.

The following table presents a profile of the graduating classes of 1986 and 1987.

Profile of Graduating Master's Classes		1986	1987 *
Number of Candidates		192	215
	US Citizens	140	165
	Foreign Citizens	52	50
Women		43	43
Members of Minority Groups		19	15
Median GMAT Score (national average is approximately 460)		640	650
Undergraduate Grade-Point Average (out of 5.0)		4.3	4.4
Undergraduate Majors			
	Humanities	7%	4%
	Social Sciences	28%	31%
	Physical Sciences	15%	19%
	Engineering	32%	31%
	Pre-Professional	18%	15%
Average Years Full-Time Work Experience		3.5	3.6
Age at Admission			
	Under 23 years	15%	9%
	23-24	30%	32%
	25-26	21%	25%
	27-28	16%	17%
	29 and over	18%	17%

\* Projected.

Overall, the Class of 1986 fared very well in the job market. Signs of a successful year began in September and continued through the spring recruiting season. Fifty-two employers (up from 38 in 1984-85) scheduled fall semester presentations to alert students to available career opportunities. A total of 159 organizations subsequently interviewed students through our recruiting program, a 12 percent increase over 1985. Most of the increase came among firms seeking graduating students, although the demand for summer interns rose slightly as well.

Approximately 80 percent of the 1986 Class had accepted employment by graduation. In terms of job function, the largest number of students (36 percent) entered financial roles. The consulting (17 percent) and marketing (16 percent) functions were next in popularity. The majority of the class will work in either New York City (33 percent) or in Boston (28 percent).

A look at graduates by industrial affiliation reveals a widening gap between students entering service vs. manufacturing organizations. Seventy-eight percent of the Class of 1986 joined non-manufacturing firms, compared with 69 percent last year. This trend holds true for MBA campuses across the country, causing concern among industry and academic leaders alike.

Student attention focused particularly on the investment banks. "Wall Street fever" surfaced early with the Class of 1986, expressing itself through Finance Club activities, summer gatherings organized by New York banks, and student lounge conversation. The end result: a doubling of the number of students entering investment banking compared with last year (22 percent in 1986 up from 10 percent in 1985). Graduates pursuing financial/investment management careers outside the banking industry also rose from 7 percent to 12.6 percent.

Next in service sector popularity were the consulting firms. They account for 18 percent of this year's hires, down from 24 percent in 1985. Even at the lower figure, the industry remains a major "consumer" of Sloan talent.

The electronics industry has traditionally hired more Sloan students than any other industry in the manufacturing sector. This held true for 1986, despite reduced hiring by most computer firms during the year. Improved business conditions by late spring produced some last-minute opportunities for the patient, determined job seeker.

In the process of pursuing permanent employment, this year's graduates moved beyond the initial screening interview with an average of eight firms. In most instances, students generated multiple offers before making their final selection and terminating the interview process.

Base salaries accepted by the Class of 1986 ranged from \$24,000 - \$78,000, with a median of \$45,000. Forty-three percent of the graduates were offered a guaranteed bonus on top of this base, with a median bonus of \$7,650 reported. A number of students were also promised additional year-end bonuses based on individual or firm performance. Signing and performance bonuses were offered across all industries, although predominantly by members of the financial services and consulting communities.

The Master's Program Committee, chaired by Professor Gordon M. Kaufman, completed, as noted earlier, the introduction of the "new" master's core. Dr. Jeffrey A. Barks, Associate Dean for Master's and Bachelor's Programs, again provided imaginative and effective administrative leadership for the master's program. Miriam Sherburne, Director of Master's Admissions and Counseling, completed her last year of full-time service to the Sloan School, but will continue to work part time during retirement. James Gabbert, Coordinator of the Master's Program, heard the call from California and has relocated to San Mateo, working for a Sloan alumnus at American Management Systems. Lucinda Hill, who came to Sloan in 1985 as Dr. Barks' administrative assistant, was chosen to replace James Gabbert, a choice which has proved to be a perfect match of talents and responsibilities. Margaret Daniels Tyler continued to direct our admissions effort with flair and efficiency, making the task of attracting and evaluating all those applicants look much easier than it is. And Linda Stantial, Director of Master's Placement, continued to run an active and productive career center for our master's students, providing the kind of attention and responsiveness to our students' needs on which we pride ourselves.

#### Management of Technology Program

The Management of Technology Program was established in 1981 at MIT and is the only program of its kind. Administered by the Sloan School of Management and the School of Engineering, this 12-month, full-time program leads to a Master of Science in the Management of Technology. It is aimed at engineers and scientists with five to 10 years of work experience, and strives to prepare these professionals for more senior roles in industry and government where they will generate and manage technology-based endeavors.

Program structure and a new curriculum were developed originally by a joint faculty committee from both the Sloan School and the School of Engineering. The curriculum includes an intensive core of analytic subjects taken during the summer and at least eight subjects allowing intensive study of the management of technical people and programs. Subjects in Managing Professionals, Marketing/Technology Interface, and Manufacturing/Technology Interface have attracted enthusiastic registration from graduate students throughout MIT, as well as from program students. All program attendees also write a thesis in the area of the management of technology, and company-sponsored individuals in particular find the thesis a golden opportunity to explore in great depth some issues of chief corporate concern.

The Management of Technology Program was conceived originally by Program Director, Professor Edward B. Roberts, of the Sloan School and the late Herbert Hollomon, Professor in the MIT School of Engineering. Admissions and daily operations are ably handled by Jane M. Morse, Program Manager, and Jacalyn

Walker-Sharp, Program Coordinator. From a pilot class of six students, the program expanded to 29 for the 1986-87 class. Plans are to continue expanding gradually toward 40-50 students per year. Though required to have at least five years of work experience before coming to the program, students average closer to 10-12 years of experience and tend to be in their mid-30s in age. They come from a wide variety of fields, including aerospace, electronics, research and development, and the military. Less than a third of each class has been foreign, with representation from several countries in Europe, also China, Japan, Israel, Argentina, and Singapore. Most students are financially supported in the program by their organization.

Program implementation would not have been possible without the strong and effective collaboration of the Deans' Offices in both the School of Engineering and the Sloan School of Management. Substantial financial contributions to fund curriculum development from Pilkington Brothers Ltd. and Gillette Company are also greatly appreciated, as are gifts from Corning Glass Works, Rogers Corporation, and Computer Services Corporation (Japan).

#### The PhD Program

During 1985-86, the Sloan School's doctoral program maintained its prominent position in the face of continuing intense competition from the other leading business schools. From 258 applications we made 38 admission offers and had 20 acceptances, acceptances that were widely distributed across our 14 concentrations:

Applied Economics	2 (foreign, male)
Finance	4 (2 foreign--1 woman, 2 US--1 woman)
Management of Technological Innovation	3 (2 foreign--male, US--1 woman)
Organization Studies	2 (US--1 woman, 1 male)
Management Information Systems	3 (US--1 woman, 2 male)
Marketing	2 (1 foreign--male, 1 US--male)
Operations Management	1 (1 foreign--male)
Operations Research and Statistics	3 (2 foreign--male, 1 US--male)

While the overall percentage of US applicants remained at approximately 35 percent, the foreign applications dropped slightly to 53 percent, reflecting decreases across all countries, including the large number of applications normally received from India, Asia, and Korea. We continue to cooperate with the efforts of the American Assembly of Collegiate Schools of Business (AACSB) to recruit more qualified US applicants, and work on our own strategies for identifying prospects and sources. During the academic year 1984-85, the PhD Program Committee initiated a marketing/recruiting effort to generate applicants we might otherwise miss and included in the application form the question, "How did you hear about our program?" Of the 238 responses, no less than 40 percent indicated professors and a sizable 20 percent, publications. These figures underscore the importance of faculty participation and visibility in exciting the interest of good students.

The bulk of the program's graduates pursue academic careers. Of the 14 graduates in 1985-86, no less than 10 embarked on such careers at Harvard, MIT, and the University of California at Berkeley, to name a few. The remaining four have accepted or are considering non-university positions.

The Doctoral Program Committee, headed by Professor Bailyn and coordinated by Sharon Cayley, has successfully grappled with the diverse problems of a very individualized program, including reducing the median time taken to complete the program (four and a half years) through early research ties to faculty, and a considerably enhanced financial aid package. For the first time in some years we are able to make financial awards much more competitive with our principal rivals.

#### Alfred P. Sloan Fellows Program

On June 2, 1986, 54 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1986 reflected a broad diversity of backgrounds and interests, and again was drawn from organizations from the United States and abroad. The Sloan Fellows Program was the first executive education program in the United States, and is now in its 55th year.

Just prior to their graduation, the Sloan Fellows completed a three-week International Management Field Trip to Asia. They visited with leading government and industrial representatives in the People's Republic of China, Hong Kong, and Japan.

A comparison of the Class of 1985-86 with previous classes follows:



	<u>77-78</u>	<u>78-79</u>	<u>79-80</u>	<u>80-81</u>	<u>81-82</u>	<u>82-83</u>	<u>83-84</u>	<u>84-85</u>	<u>85-86</u>
<u>Industry</u>									
United States	26	31	30	31	30	28	26	30	26
International	14	10	11	13	15	13	15	13	12
<u>Government</u>									
United States	8	5	5	8	7	10	8	9	10
International	5	2	1	0	0	2	5	3	4
<u>Other</u>									
World Bank	0	0	0	0	0	0	0	0	0
Municipal Management	0	0	0	0	0	0	0	0	1
Medical Management	2	6	5	2	4	3	4	3	2*
Church Management	0	0	1	0	0	0	0	1	0
University Management:									
United States	0	0	2	1	1	1	1	1	1
International	<u>0</u>	<u>0</u>	<u>1</u>	<u>1</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
	55	54	56	56	55	55	56	57	54*

\* Medical Management Sloan Fellows also counted in US Industry and University category.

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 13, 1986, the Class of 1986-87 arrived; there are 56 participants in the 1986-87 program.

The Director of the Sloan Fellows Program, Alan F. White, is an alumnus of the program (Class of 1971) and once again performed efficiently and effectively in a very challenging role. Professor Arnoldo C. Hax served as chairman of the faculty program committee.

#### Health Management Executive Development Program

The 11th year of operations was completed by the Health Management Executive Program as an integral part of the Alfred P. Sloan Fellows Program. There were two Sloan Fellows from the medical field: William J. Culp, Associate Professor, Dartmouth Medical School; and Delwin K. Ohrt, Medical Director, Laboratory of Clinical Medicine.

#### Program for Senior Executives

In Fall 1985 the program celebrated its 30th anniversary with the completion of the 60th program. The program continues to attract outstanding senior executives from private and public organizations around the world. The Spring 1986 program contained the broadest international mix ever, with representatives from 18 foreign countries in attendance. New features in 1985-86 included an exercise program and optional tutorials on the use of spread-sheet programs with personal computers.

The Director of the program is Dr. Edwin C. Nevis, a member of the core faculty of the program from 1978-84. Professor Henry D. Jacoby continues as Chairman of the Faculty Committee.

#### Greater Boston Executive Program

Continuing to serve as an important link between MIT and the Boston area community, the Greater Boston Executive Program enrolled 22 participants in the 1986 session held from January 24 to May 2.

The executives, 19 men and three women, met each Friday for 15 weeks for sessions on economics, finance, accounting and control, human resource management, marketing, and strategic planning offered by the Sloan School faculty.

#### Summer Programs

During the 1985 Summer Session, Sloan School faculty participated in 11 Special Summer Programs.

Nine of the programs were of one-week duration. The Management of Research, Development, and Technology-Based Innovation, directed by Professor Roberts, continued as a two-week program and also continued to attract a large audience. A new program, Managerial Decision Making, offered by Professor John S. Carroll, was limited to two days.

Three of the one-week programs were held as live-in programs at the MIT Endicott House and Conference Center in Dedham: The Executive Program in Financial Management, coordinated by Professor Myers; Operations Management, The New Production Planning, chaired by Dr. Harlan Meal; and Corporate Strategy, Strategic Planning Systems, coordinated by Professor Hax.

Professor Max Bazerman co-directed a new program, Bargaining and Negotiation, with Professor Lawrence Susskind of the Department of Urban Studies and Planning.

The remaining programs had all been offered in previous Summer Sessions: Decision Support Systems and the Management of End User Computing (Professors John C. Henderson and Michael E. Treacy); Medical Technology Assessment for Health Professionals (Dr. Finkelstein); Corporate Planning and Control Systems (Dr. Morris McInnes); Corporate and Economic Policy Design with Microcomputers: The System Dynamics Approach (Professor John Sterman and David Kreutzer); and Operations Management in the Service Industries (directed by Professor Richard Larson of the Operations Research Center, assisted by Professor Gabriel R. Bitran).

In addition to these programs offered as part of the Institute's Special Summer Programs, several members of the faculty and staff directed and participated in two other sessions. The Center for Information Systems Research offered its 10th annual summer meeting seminar on Current Issues in Management Information Systems at the Hyatt Regency in Cambridge. In August the School co-sponsored with MIT's Center for Transportation Studies a one-week seminar on Logistics Analysis for Carriers and Shippers.

Another special seminar sponsored by the School was the Marketing Center's special symposium on Marketing Management Frontiers held in late May 1986. This was a three-day seminar held at Endicott House.

#### Industrial Liaison Symposia

Sloan School faculty also chaired or participated in several of the Industrial Liaison symposia held during the year. In April, Professor Michael S. Scott Morton chaired Management in the 1990s held in San Francisco. In May, Professor Robert B. McKersie was chairman of the symposium The Corporate Edge of the New Industrial Relations; Professor Bitran was a co-chairman of Manufacturing in the 90s; and Professor Denis F. Simon chaired China's Modernization Program: Implications for Business. The May symposia were all held in Cambridge.

The Industrial Liaison Office also sponsored a few short international courses and three of these were directed by Sloan faculty. Professor Roberts directed Management of Research, Development, and Technology-Based Innovation in Haifa, Israel, during January, and in London, England, during May. Professor Hax went to Stockholm, Sweden, in June to conduct Strategic Management: New Directions.

#### RESEARCH

This section summarizes the major research efforts and accomplishments of the School. This work is both disciplinary and multi-disciplinary in character and is grouped here under three main headings corresponding to the major clusters within which the School's faculty are currently organized: Behavioral and Policy Sciences; Economics, Finance, and Accounting; and the Management Sciences Areas. The section does not include detailed references to the substantial research efforts and participation of the Sloan School faculty and staff in the activities of many of the Institute's interdepartmental centers or laboratories. These are described in the separate center or laboratory reports.

#### Behavioral and Policy Sciences

A broad range of managerial issues is encompassed in the Behavioral and Policy Sciences Area. These range from context specific subjects like international management, technological innovation, and human resource management through process activities such as strategy and policy. Underlying are the disciplinary foundations of management, including organization studies and the psychology of individual decision making. Through this diversity run certain unifying themes, in particular, those contained in the name of the area: behavioral science concepts and policy-oriented problem-solving.

A hallmark of the area is multi-disciplinary research and nowhere is this more evident than in the School-wide project, "Management in the 1990s," directed by Professor Scott Morton of the strategy and policy group. The project, now in its second of five years, is a five-million-dollar research effort sponsored by a consortium of companies and government agencies. It is examining the changing nature and content of management as affected by the new information technologies. The research team draws from the whole School but contains major efforts by the Behavioral and Policy Sciences faculty. Included are members from strategy and policy, organization studies, industrial relations, international management, and technological innovation.

Classifying the faculty's research requires a certain amount of arbitrariness because of the overlap and intermixing of subject matter. In the descriptions that follow we shall try to point out some of the interconnections. For example, human issues are central to the management of an organization and similarly

critical to the relation of organizations to each other and to their economic, social, and political environment. The faculty in organization studies and industrial relations have their primary research in these areas and frequently have overlapping and complementary interests, particularly on the subject of human resource management.

Organization Studies faculty are concerned with understanding the relation between the individual and the organization and the dynamics of behavior in organizations. Professor John E. Van Maanen continues his long-standing work on comparative socialization practices, with special reference to police organizations. He has also embarked on a new topic, which may be described as the "management of emotions," and is typified by the task of an organization like Disneyland, which, through its employees and physical surroundings, seeks to provide a happy experience for its customers. Professor Edgar H. Schein, in part with support from the "Management in the 1990s" project, has initiated a 25-year follow-up on his panel of master's degree alumni from the 1960s. This unique data source will again provide information on career evolution and, in addition, will be used to study the adaptation of a particular managerial generation to computer technology at work and at home.

With the support of a research grant from General Motors, Professor Bailyn has been examining autonomy in industrial R&D laboratories, relating this to career orientation, career stage, and performance. She is also analyzing data from a sample of 473 men and women in technical careers as part of her research on work and family, personal orientations, and burnout. In a further project, sponsored by "Management in the 1990s," she is collecting data in the United States and in the United Kingdom on work at home, particularly as it is facilitated by new information technologies. She finds widespread resistance by managers to work at home because of their preference for "visible" employees.

Professor Carroll is studying judgment and decision-making behavior in negotiating tasks with a specific concern for the way negotiators understand their opponents' thinking. This work is being supported by the National Science Foundation's Decision and Management Sciences Program. As part of the "Management in the 1990s" project, Professor Carroll is also studying the introduction of microcomputers in large corporations at two company sites. His concern is with the impact of expectations on implementation strategy and process.

The research of Professor Deborah L. Gladstein deals with how groups in organizations adapt to their environments and, in particular, how they manage the boundaries between themselves and other parts of their organization or the external world. Currently she is working with new product teams in high technology companies to explore their boundary management behavior in resource dependent environments and how this influences group effectiveness. Professor David G. Anderson has been studying corporate revitalization: how large companies plan and implement major changes in strategy, organization, and culture. The work has been extended with the addition of two more case studies conducted by Sloan Fellows. In another area he has undertaken a project on process innovation in the context of large-scale organizational change, funded by "Management in the 1990s."

In the other part of the Behavioral and Policy Sciences Area that specializes in human issues, the Human Resource Management and Industrial Relations subgroup, Professors McKersie and Thomas A. Kochan, along with Professor Harry Katz of Cornell, have completed a manuscript, "U.S. Industrial Relations in Transition," that summarizes their five-year project on the subject funded by the Sloan Foundation. Professors Kochan and McKersie are continuing their research on changes in industrial relations under a grant from the US Department of Labor. In particular, they are studying the staying power of various types of innovations. The introduction of new technology raises many important employment questions. Under the "Management in the 1990s" project, Professors McKersie and Kochan are examining training and re-deployment issues. Professor McKersie has also been examining the effect of changes in work rules in the airline industry, mapping the interplay among business strategy, changing competitive conditions, and industrial relations developments.

Professor Lisa M. Lynch's studies of employment and unemployment of young people in the US have turned up a variety of significant findings from data in the National Longitudinal Survey: Young males have reduced chances of finding successful employment the longer they remain unemployed. Non-governmental types of training produce significant economic returns for the money spent but governmental programs do not. The labor market experiences of non-white and white males and females are distinctly different. In further work, this time in a study of employer initiated union decertification elections, Professor Lynch has uncovered a number of results, including a surprisingly high concentration of such elections in the US Northwest.

Research on non-union complaint systems is under way by Professor Mary P. Rowe with a pilot study of the structure and function of corporate ombudsman offices. She has also written a provocative piece on the fear of AIDS.

The 10-year study of 360 Sloan School graduates from five classes (1975-79) by Professor Wallace has now yielded important insights. One widely cited result is that five years after graduation Sloan women who are full-time employees do as well as their male counterparts. Professor Wallace is preparing a book manuscript on the research. At the end of this academic year Professor Wallace officially retired, but

we note that not only is she actively continuing her research and writing, but she has also become president-elect of the Industrial Relations Research Association, a signal honor. It is a pleasure further to report that Professor Wallace was awarded an honorary degree from Brown University at its commencement exercises in May.

System Dynamics. Over the past several years research has focused on the System Dynamics National Model of economic behavior. The model itself is now substantially complete and attention has turned to a series of books that describe the model and the insights that have come out of it. Work on the national model has been conducted by Professors Jay W. Forrester and John D. Sterman, and Research Associates Peter M. Senge and Alan Graham.

Professor Sterman has been turning his attention to the theoretical and empirical foundations for simulation modeling of decision-making behavior. This requires relating aggregate decision rules in simulation models to micro empirical knowledge developed in behavioral decision theory and other behavioral science. Using a direct experimental approach, he has conducted a microcomputer-based capital investment game with a large, diverse sample of subjects. Their pattern of decisions over time compares closely with that of the formal rule used in an aggregate level simulation model. In other work he has been testing the adaptive learning model often used in system dynamics to represent the effect of expectations. Using historical data on energy consumption and forecasts of its future consumption, he finds that his aggregate rules reproduce the forecasts quite well.

Another major thrust in system dynamics lies in the corporate policy area. Professor John D.W. Morecroft has developed a framework that combines system dynamics with concepts from organization theory and behavioral decision theory into a flexible tool for business policy research. He has successfully tested this framework in a case study of sales planning and control in a data communications company.

Management of Technology. Increasingly competitive international markets and a large trade deficit have turned national attention to technology as a source of new products and improved manufacturing productivity. Questions of managing technological innovation, capturing its benefits, and incorporating technological change into company strategy take on increased importance both for the firm and the economy. Professor Eric A. von Hippel has been doing research and writing on these topics. Recently, he and Professor Glen L. Urban of the marketing group have demonstrated the efficacy of their concept of 'lead users' for evaluating radical new product concepts. They have shown that a manufacturing firm, in this case one dealing with computer-aided design, can specify a field of interest, find lead users in it, and obtain from them high-value marketing research information. In new work Professor von Hippel is discovering that the diffusion of technical knowhow is facilitated to a surprising degree by the trading of proprietary information by engineers in competing firms. He further has developed models that explain why this may be quite sensible behavior.

Professor Thomas J. Allen is conducting research under the sponsorship of the "Management in the 1990s" project, in which the communication patterns of 750 software engineers are being monitored for a period of 18 months while their communication capabilities via personal computer work stations and networks are gradually improved. He is also beginning a follow-up study under National Science Foundation sponsorship of career progress of a group of engineers and managers in an R&D laboratory studied six years ago. In another study he is examining communication patterns in a new Corning Glass building designed to increase communication by maintaining high visual contact between floors with an atrium and relatively easy vertical transportation with escalators, elevators, and open stairways. He will compare communications in this setting with that in several other buildings.

Professor Roberts continues his research in areas of new product strategies of small high technology companies as well as on new venture strategies of large companies. He has also finished writing up his research on the formation and growth of new biomedical enterprises.

Strategy and Policy. Domestic and international competition in the business world has heightened in recent years, causing corporations to put more emphasis on strategic issues. Within the Sloan School a surprising number of faculty with disciplinary backgrounds have, over the past few years, become interested in the strategic problems of the firm. Several of these have moved to the strategy and policy subgroup where they have been joined by young faculty hired directly into the field. Because of the wide interest within the School, the core group is interconnected well with such other areas as organization studies, international management, marketing, finance, and the management of technology.

Professor Hax's work this past year has been oriented toward expanding our understanding of a large number of intertwined issues including strategies for growth and diversification, mergers and acquisitions, global management, the value chain and competitive advantage, and the linkage between horizontal strategies and vertical integration. In this effort he has been working closely with Visiting Professor Nicolas Majluf and two groups of students, 28 in all, doing field work in companies as part of their master's theses.

As mentioned earlier, Professor Scott Morton is director of the "Management in the 1990s" project. Within it he has a personal research interest in identifying the role that information technology plays in enabling (or inhibiting) major organizational changes. He is looking at examples of such changes in four US firms and their European components. Observations to date support the view that information technology not only permits change but knits the resulting organization together in new ways.

Professor Mel Horwitch has been studying large-scale enterprise with a special emphasis on the characteristics and limits of professional strategic management in attempting to deal with the issues brought about by scale. He is also investigating the changing relationship between technology and strategy in technology-based industries.

The current interests of Professor N. Venkatraman focus on the issues of measurement in strategy research, that is, the schemes necessary to link verbalizations of theories to empirical operationalizations. This work includes the development of measures to describe the strategic orientation of a firm and the operationalization of business performance from a strategic perspective.

The problem of managing vendors and their markets has concerned Professor Gordon Walker, who has brought to bear analytic methods from economics and organization theory. He is also working on organization design in information intense organizations, approaching the problem as a task network which he operationalizes using blockmodeling techniques. Professor Zenon S. Zannetos, although his primary energies are absorbed by School resource development, continues his long-standing research on industry productivity analysis and the economics of ocean transportation.

International Management. One cannot read the daily newspaper without sensing the global forces that have brought the issues of the multinational corporation and international management into prominence. The Sloan School, as is true of the rest of MIT, has always attracted substantial numbers of non-US students and its faculty has consistently maintained communication with many other countries.

One of the lines of research being conducted by Professor Donald R. Lessard concerns external finance for developing countries. He finds the structure of their external obligations to be a major contributing factor to the current debt crisis and has been seeking an understanding of factors that may be barriers to alternative patterns of finance. In other work he has studied the measurement and management of international exposure to exchange rate fluctuations with a particular emphasis on the linkage between finance and operations. Professor Richard D. Robinson has continued his work on international technology transfer and has a book under way on the subject.

In recent years the international management group has developed significant strength in Pacific rim affairs through faculty members Professor D. Eleanor Westney, a Japan scholar, and Professor Denis F. Simon, a China specialist. Professor Westney has been doing a comparative analysis of the careers and the organization of engineers in R&D in the computer industry in three Japanese and three US firms. She is also engaged in field research on an environmental scanning project that is part of the "Management in the 1990s" program.

Professor Simon has been doing research on technology transfer and the assimilation of technology into developing countries. A current study concerns the modernization of Shanghai's electronics industry. His research analyzes how changes in China's economic climate affect the behavior of firms regarding technological innovation and foreign technology acquisition. Another project is examining the variables that determine the key sources of innovation in Chinese industry.

Health Care Management. The efficient and effective delivery of health care is a major economic and social issue. The Sloan School, through the research of its faculty and their involvement in the Division of Health Policy and Management of the Whitaker College, continues to play an active role. Dr. Finkelstein, who directs the interdisciplinary Laboratory for Health Care Studies in Whitaker, is doing research on a variety of topics. Currently he is doing a cross-state comparison of solid organ transplant policies. The goal is to classify different approaches and relate them to such issues as the relation between clinical experience and success rates. In another new study he is seeking to relate laboratory cost changes to test volume in a radiology department. A continuing interest concerns insurance coverage decisions for emerging medical technologies. He seeks to understand the nature of the information that is sought and used for the coverage decision and to measure its potential to change the practice behavior of physicians. In work that spans the technology and health areas, Professor Roberts, as mentioned earlier, has been studying the formation of biomedical firms, including consideration of their linkages to medical schools and hospitals and the impact of federal regulations.

Law. Professor J. D. Nyhart makes a persuasive case that law, traditionally only a teaching area at the Sloan School, should also be a subject for research. He has identified several promising directions for a research effort. One of these is alternate methods of dispute resolution. He has been particularly active in conflict resolution over issues arising in use of the oceans, the coastal zone, and the continental shelf.

In addition he has been working with Senior Lecturer Gordon F. Bloom to establish an organization called the Massachusetts Critical Issues Forum. This is a committee of respected leaders from industry, government, and public interest groups, who have as their objective the resolution of controversial issues through consensus supported by research. Dr. Bloom has also been engaged in intensive work growing out of the liability explosion and on problems relating to hazardous waste disposal.

Communications. Dr. Yates has been researching and writing a scholarly book on internal communications within American firms during the period 1850-1920. She has written most of a case study on du Pont, the second of three case studies for the book, and has done the research for the third case, on the Illinois Central Railroad. She has further collaborated with Professor Malone and Visiting Scientist Robert I. Benjamin on the effects of contemporary information technology on firms and markets.

#### Economics, Finance, and Accounting

Research in the Economics, Finance, and Accounting Area is grounded in Economics and directed to specific applications in management and public policy. Of the three groups included in the area, Applied Economics is the most diverse in its research, which ranges from the most important current policy issues in macro-economic policy to difficult mathematical problems in applied econometrics.

Research in Finance focuses on understanding the behavior and development of money and capital markets and draws implications for corporate finance and investment management. Financial research is steadily becoming more exciting and challenging, reflecting the rapid "internationalization" of capital markets, the changing roles of financial intermediaries, and the introduction to new securities and trading strategies.

Research in Accounting focuses not so much as finding the "correct" accounting procedures, as in understanding how the procedures actually in use convey information and affect managers' or investors' decisions. For example, much recent research in Accounting uses techniques from financial economics to test how the signals conveyed by corporate announcements of earnings per share and other accounting variables affect investors' assessment of the value of the firm.

This year's happiest and most dramatic event in Economics, Finance, and Accounting was the award of the Nobel Prize in Economic Sciences to Institute Professor Franco Modigliani. The award recognizes a long and exceptionally productive research career in macroeconomics and financial economics. The award specifically cited Professor Modigliani's development of the life cycle hypothesis of saving and the so-called MM theory of corporate finance, which was developed jointly with Professor Merton H. Miller of the University of Chicago.

Applied Economics. Professor Ernst R. Berndt continued work on productivity measurement and on the interactions between energy price shocks and multi-factor productivity growth. Among other projects, he has collaborated with Dr. David Wood, the Director for the Center for Energy Policy Research, to estimate inter-industry differences in productivity growth in the United States and to compare differences in productivity growth between the United States and Japan. He received initial National Science Foundation funding for investigation of alternative approaches to measuring international competitiveness.

Professor Jacoby's primary research activity is the analysis of energy resource projects using methods of options valuation. The focus thus far has been on the evaluation of oil tax regimes, treating the Government's tax claim as a call option on project income. This work should throw new light on long-standing disputes about the effects of these tax systems, with their ring-fencing provisions and high marginal tax rates.

Professor Robert S. Pindyck was on sabbatical at Tel-Aviv University in Israel. He developed a model of the optimal timing of investment in capital assets, when investment takes an extended period to complete. Investment is modeled as a series of interrelated call options on the completed investment. He collaborated with Professor Saman Majd, of the Wharton School at the University of Pennsylvania, on this work.

Professor Nancy L. Rose's major research during the past year focused on the investigation of the effects of motor-carrier regulation and its reform on the trucking industry has developed evidence that regulation created monopoly profits, some of which accrued to owners of trucking firms. She has also found that union workers received substantially less favorable wages after trucking deregulation in 1980. She plans to extend the research to study the effect of both trucking and airline deregulation on safety.

Professor Julio J. Rotemberg has continued his work with Professor Garth Saloner, of the MIT Economics Department, on the consequences of strategic interactions upon firms, output, pricing, and investment decisions. They have written three papers on this topic. One explains why price leadership helps industries stay collusive. The second explains why, in practice, monopolies tend to keep their prices constant for longer periods of time than oligopolies do. The third paper shows that in an international trade context quotas have the potential for increasing competition in the protected market. In addition to his work with Professor Saloner, Professor Rotemberg has written a paper showing that export promotion may indeed be necessary for countries to signal their ability to export successfully; yet, if signalling is the reason for export promotion, encouraging other countries to promote exports can be counter-productive.

Professor Edwin Kuh served as Director of the Center for Computational Research in Economics and Management Science. His recent research continued to address two topics: regression stability analysis and guided computing. His work on regression stability analysis has generated a significant advance in understanding how to test and find the limits of testing in regression models, especially ones subject to outliers. Guided computing concerns the application of expert system concepts to quantitative analysis, mainly regression.

Professor Richard Schmalensee was on sabbatical leave at Harvard Business School. He completed work on collusion in the presence of cost differences, using economic analysis, and programming methods in a new product design (with Jacques Thisse of CORE), and on the results of, and prospects for, cross-section empirical work in industrial organization. He is co-editor of the forthcoming Handbook of Industrial Organization, with Robert Willig of Princeton.

Professor Thomas M. Stoker's research was in three categories: the first concerns issues relating to aggregation and studies of microeconomic and macroeconomic data. Second, he analyzed the impact of individual heterogeneity in estimated macroeconomic equations. Third, he continued work on individual and aggregate demand for energy and non-energy commodities.

Professor Lester C. Thurow worked on why United States productivity growth has been slower than in other countries, on the nature of the US competitive problem vis a vis the rest of the world, and on income distribution problems.

Finance. Professor John C. Cox worked in the general area of dynamic investment strategies. One result is a description of continuous time, process-free investment strategies, which unlike traditional strategies do not require prior description of the process followed by asset prices. One important application is a theory of investment where the specification of the underlying model of security prices is not corrected in each moment in time, but is correct on average. Process fee investment rules can be used to generate a desired return pattern exactly.

Professor Daniel M. Holland continued his work on an inter-industry team that is preparing a major tax reform proposal for Jamaica. He is the leader of the company tax group, which expects to finish its report by the end of 1986. He is also working on a paper on user fees and charges for the Massachusetts Reform Commission.

Professor Chi-fu Huang worked on several research projects during the past year. First, he collaborated with Professor Darryl Duffie, of Stanford University, on the study of stochastic dynamic production economies. They are the first to attempt to incorporate production in a continuous time model with heterogeneous agents. Second, he worked with Professor Cox on intertemporal portfolio theory. Their paper describes a variational technique proving the existence of optimal strategies in continuous time securities markets. They plan to apply this technique to characterize investors' optimal trading policies. Third, Professor Huang continued work with Professor Robert Litzenger, of the University of Pennsylvania, on a book tentatively titled "A Course on Financial Economics."

Professor Terry A. Marsh has continued his work with Professor Robert C. Merton on volatility tests of stock market rationality. They show that recent attempts to test behavioral theories of stock market behavior, as well as theories of rational speculative bubbles, have serious flaws. He has also collaborated with Professor Paul M. Healy in examining market expectations of future earnings as a function of lagged stock returns. Their results indicate that standardized accounting earnings changes are significantly associated with contemporaneous and the prior years' returns. Further, the lag relation appears to be related to the growth opportunities of the firm.

Aside from his work with Professor Marsh, Professor Merton continued research on the pricing of fixed income securities and related options and futures contracts on these securities. He has completed two extensive entries, "Options" and "Continuous Time Stochastic Models," for The New Palgrave, an enormous undertaking by the Macmillan Press to produce a new version of the 19th Century Palgrave Dictionary of Economic Theory and Doctrine.

As was noted above, Institute Professor Modigliani won the Nobel Prize for Economic Sciences. His Nobel lecture, "Life-Cycle, Individual Thrift, and the Wealth of Nations," was delivered in December at the Stockholm School of Economics. It presented a review of his work on the life-cycle hypothesis of savings and other research and applications it has generated. An extended version of that paper was presented as the Killian Lectures at MIT. He was also awarded "Cavaliere de Grand Croce" (Knight of the Grand Cross) by the President of the Republic of Italy.

Professor Modigliani has pursued his interest in the issue of whether public deficits tend to reduce national saving or are at least partly offset by a rise in private saving. He has completed a paper with Arlie Sterling, showing that for the United States there is no evidence that public dissavings is offset by private savings. He has completed a separate paper with Tullio Jappelli, covering the Italian experience back to the beginning of the Italian state in 1860. In this case, there is some effect of the public deficit on private savings, but it is small.

Professor Myers collaborated with Professor Majd, of the University of Pennsylvania, on a paper entitled "Tax Asymmetries in Corporate Income Tax Reform," which applies option pricing methods to value the Government's tax claim in a risky venture in the absence of full-loss offsets. Professors Myers and Majd show that current tax reform proposals would dramatically reduce the effect of tax asymmetries.

Professor Myers also collaborated with Professor Richard A. Cohn, of the University of Hartford, on a paper showing how to apply modern financial techniques to property liability insurance rate regulation. He has also continued work on sequential investment and financing decisions in the venture capital market.

Professor John E. Parsons worked on the application of recent advances in the economics of information and the theories of games to problems in finance. He published a paper with Professor Arthur Raviv, of Northwestern University, on the market for seasoned issues of stock. They show that the price of a new issue and the revenue raised from the sale are not identically determined by prior prevailing stock prices, but rather depend in a predictable fashion on the method of sale chosen. Their models reinterpret the reasons for the underpricing of new issues.

Professor Parsons' research on financial contracts estimates the value to a firm of a long-term purchase and supply commitment for a commodity produced or used in a piece of major plant and equipment. He has also continued studies of counter-trade agreements and financial contracting in the German Democratic Republic.

Professor Richard S. Ruback completed a paper with Professor Wayne Mikelson, of the University of Oregon, measuring the common stock valuation effects of corporate investments in other companies' shares. He completed a paper with Professor Carliss Y. Baldwin, of the Harvard Business School, considering the effects of inflation on a firm's choice between assets of different lives. The paper focuses on the impact of inflation and interest rates on the value of nominal depreciation tax shields, and shows the effect of an inflation-induced increase in nominal interest rates on the break-even prices of short- and long-lived assets.

Accounting. Professor Healy's joint work with Professor Marsh was mentioned above. In addition, he completed work on a paper testing whether top executives' bonus and salary compensation is adjusted following changes in accounting methods. The results indicate that salary and bonus payments are based on reported earnings, rather than earnings under the original accounting method. He is also collaborating with Professor Krishna Palepu, of the Harvard Business School, on the information effects of announcements of dividend initiations and new equity issues.

Professor Sudhir Krishnamurthi collaborated with Professor Ram Ramakrishnan on modeling management control systems. They analyzed "ratcheting" in budgets, by which organizations tighten the budget if it is met, and relax it if it is not met. They show that ratcheting introduces gaming on the part of managers, but that organizations nevertheless gain. They also collaborated on a study of the information content of corporate earnings, analyzing how the relationship between earnings and prices depends on fundamental factors that vary across firms. In addition to his work with Professor Ramakrishnan, Professor Krishnamurthi has studied time series earnings forecasts for small firms, and has started an investigation of the dividend yield effect in capital asset pricing.

Dr. McInnes collaborated with Professor Ramakrishnan on analysis of the effectiveness of budgeting and control systems. He continued his work on the corporate management of productivity.

Professor Patricia C. O'Brien completed a paper investigating alternative definitions of consensus when a variety of forecasts is available. She finds that commonly used aggregations, such as the mean or median, are dominated by the single, most recent forecast available. She has also been testing whether some analysts can consistently forecast earnings with superior accuracy. She finds no evidence of individuals with such ability.

In addition to his joint work with Professor Krishnamurthi and Dr. McInnes, Professor Ramakrishnan has developed several models of management control systems, which he uses to analyze information and the motivation of managers. He has used information economics and agency theory frameworks to investigate responsibility center design, incentive contracts, and executive compensation in conglomerate firms.

#### Management Sciences

Decision support systems and expert systems have become watchwords of the 1980s. New computer, communication, and manufacturing technologies, as well as information sources for executive decisions, continue to evolve at a staggering pace, and managers are increasingly coming to realize the importance of improved methods and systems for supporting their decisions. This awareness, in turn, poses significant challenges to universities to develop a better understanding of information flow and decision making. The issues are far-reaching. How do the new technologies affect the ways in which individuals and groups make decisions? How should, and will, organizations change to respond to this new managerial environment? What techniques are required to generate, calibrate, store, and act upon the massive amounts of data now available? How might managerial practices in the traditional functional areas of marketing, manufacturing, and distribution change in this new environment?



Since its inception in the late 1960s, the Management Science Area of the Sloan School has been at the forefront of research on these issues. The interests of its faculty range from generic methods and theories of information science and decision making to issues of planning, implementation, and organizational impact in a variety of contextual domains. The area approaches these issues from its traditional disciplinary strengths in computer science, operations research, and statistics, as well as from an expanded methodological base that embraces paradigms from behavioral science and economics. Through its participation in several of the School's research centers and large-scale projects (Marketing Center, Center for Information Systems Research, "Management in the 1990s" research project), it also collaborates with a variety of practicing decision makers in setting and carrying out its research agenda. In addition, the area's faculty draw considerable stimulation from its active participation in several research centers at the Institute (Operations Research Center, Artificial Intelligence Laboratory, Statistics Center, Center for Transportation Studies).

The following brief research summary, organized by four subgroups, highlights a few of the area's activities from this past year. As this summary indicates, the area's broad-based research is distinguished by a balance of theory and applications and by the overarching normative theme of improving managerial decision making.

Marketing. Marketing at MIT has always been distinguished by its emphasis on model building and the integration of theory building with validation and testing in practice. The research this past year continued in this tradition, and also expanded to include an important set of behavioral issues.

Professor John R. Hauser's research increasingly focused on issues of marketing competition that bring together ideas from operations research, economics, and behavioral science. For example, he wrote papers on price and positioning strategies and on advertising strategies. He also continued to collaborate with Professor Glen L. Urban on consumer purchasing of durable products using prelaunch forecasting of automobiles as a testbed. Professor Urban worked on a wide variety of other issues, including order of market entry on market share, industrial segmentation, marketing/technology interface, and marketing strategy. Professor Deborah L. Marlino examined simplifying heuristics or processing shortcuts that consumers use when forming product judgment. She also studied the advantages of pioneer market entries in capturing market share and began to study the effects of product categorization on product evaluation. Professor McAlister continued to focus on the analysis and management of promotion expenditures--for example, the impact of price promotions on market share or on the management of a product line. She also completed work on channels of distribution and on variety seeking behavior. Professor John D.C. Little worked on brand choice models that are calibrated on household panel data collected by optimal scanners in supermarkets. In particular, he developed a new method for measuring the effect of cents-off coupons distributed in newspapers. Dean Alvin J. Silk, in addition to his administrative responsibilities, continued to work on detecting attitude shifts in advertising field experiments and on strategic and organizational alternatives in creative advertising policy.

Operations Management. The operations management group initiated a new collaborative research program this past year with industrial sponsors. The program is aimed to more formally recognize, and build upon, the group's previous tradition of working with industry to develop new theories and models of operations management as extracted from the study of real operating situations. This initiative also permits faculty to more easily collaborate on common research themes--e.g., manufacturing in high technology industries.

For example, Professors Graves and Charles H. Fine and Dr. Meal are jointly studying production planning and scheduling for the manufacture of large-scale computer systems. Professor Graves and Dr. Meal completed their research on production planning in a dynamic environment, and Professor Graves studied production planning in job shops and in multi-staged systems. Professor Fine continued to work on quality control and quality improvement and on the economics of flexible manufacturing technologies, and began to examine issues of workforce flexibility. He also initiated collaboration with Professor Lode Li on optimal entry and exit and technology choice for oligopolistic industries. In addition, Professor Li studied flexible manufacturing technologies, the economics of information, and manufacturing technology transitions. Professor Bitran, working with several industrial sponsors, developed models and algorithms for production scheduling for high technology goods including semiconductors, silicon wafers, and microwave connectors. He also began new research on dynamic stochastic production planning and on networks of queues and their application in manufacturing.

Management Information Systems. The management information systems group's diverse research continues to be stimulated by the extraordinary impacts of rapidly changing information technology. The group's research ranges from behavioral issues related to end-user computing to technology issues concerning data base architectures. The group is also at the forefront of research on decision support systems and expert systems.

For example, Professor Randall Davis's research aims to develop expert systems with a deeper understanding of problem domains than that of current systems and, therefore, the ability to better emulate humans in dealing with novel problems. He also continues to study expert systems that design products for testability, and artificial intelligence and signal processing. Professor John Henderson examined how computer-aided planning and design tools impact managerial processes and affect design team performance and group

decision making. He also studied how (shared) assumptions can affect the validity of information system plans. Professor Malone's research focused on designing computer systems that help groups of people work together, including such topics as expert systems for intelligent information sharing and computer-mediated group decision making. He also continued to work on theories of organizational structure and on the impact of information technology on organizational structure. Dr. John F. Rockart continued to study a variety of issues related to management use of information resources. Based upon several extensive field studies, he proposed conceptual frameworks for management of data resources, executive support systems, and the role of the line manager in information systems. In addition, he co-authored a book that compiles most of the significant findings of the Center for Information Systems Research since its founding. Professor Treacy pursued his research on developing techniques for evaluating the impacts of information technology on managerial and organizational productivity. As part of this research, he began a major field study to develop a real life data base and to test his methodologies in practice. In a collaborative research effort, Dr. Amar Gupta, Dr. Hoo-Min Toong, and Professor Stuart E. Madnick continued to study novel computer architectures for large-scale data base machines, including plans for building a prototype machine. Professor Madnick also placed increasing emphasis on a project to use systems dynamics methodologies to model the software development process.

Operations Research and Statistics. Operations research and statistics at MIT is noted for its balance of theory and application. Research this past year has continued this practice by considering both algorithms and methods of decision making and applications to a variety of problem domains including criminal justice, health care, logistics, and manufacturing.

Professor Kaufman continued to study sampling methods for finite populations and successive estimators. He also embarked upon new research to examine the stochastic modeling of software bugs in computer programming, in part by applying his previous research concerning models of natural resource discovery. Professor Arnold I. Barnett's research aims to use probabilistic modeling to shed light on public policy issues: in addition to pursuing his long-term investigation of criminal justice systems, he began new research on aviation safety. Professor Roy E. Welsch continued to develop expert systems for computer-guided solutions to statistical problems with the system providing strategic advice on appropriate methods. By using new techniques in simulated annealing, he also extended his long-term development of statistical methods that ensure robustness to aberrant data. In methodological research, Professor Wong developed new methods for clustering diagnostics. In applied work, he studied attitude measures in marketing, concentration of business markets, and two issues in health care--grouping of viral samples based on antibody activity and the effects of dental insurance on case mix and price of dental services.

In the area of mathematical programming, Professor Jeremy F. Shapiro completed several application projects in manufacturing, logistics, and finance. He also conducted research on stochastic optimization and initiated new work on the use of parallel processing for novel implementation of decomposition methods of optimization. Professor Robert M. Freund studied methodological issues in linear and nonlinear programming, and fixed point theory. He also completed research on investment decisions in flexible manufacturing systems. Professor Orlin developed new results for a variety of problems in combinatorial optimization, including the only known polynomial time variant of the simplex method for network flow problems. In addition, he worked on emergency scheduling for the military sealift command. Professor Thomas L. Magnanti studied several issues in integer programming, including the development of a new algorithm for large-scale network design problems, and improved modeling for capacitated facility location and capacitated production planning.

#### EXTERNAL RELATIONS

Efforts toward strengthening the relationships between the School and its external constituencies continued at high gear during the academic year 1985-86. We have made fine progress in this respect over the past few years, but aspire to do even better. These efforts are aimed not only at our alumni and alumnae but also at organizations which are and should be recruiting at Sloan, corporations which make use of our educational programs, organizations targeted for cultivation, and individuals--both alumni/ae and non-alumni/ae--who are in a position to assist the School either financially or otherwise.

The Sloan School of Management is small and very young in comparison to other first-rate business schools. As a result we do not have a large alumni/ae constituency to spread the word about the School, and must work both harder and more intelligently in the area of external relations.

We have learned from experience that those who get to know us are very impressed with what we are and what we have to offer. So our strategy is to increase the variety of contacts between the School and the outside world.

During the past two years we have also been able to record continued increases in contributions to the School and we are extremely gratified by the implied loyalty of such enhanced giving.

Contributions and pledges to the Miriam Sherburne Fund have reached a total of over \$200,000. A modest goal of \$5,000 back in 1983 was successively increased four times to the present \$200,000 level. This brings to a conclusion a drive that reflects credit to both Miriam, who is formally retiring from full-time work with us after 49 years of dedicated service, and to the many alumni/ae who fondly remember her as a caring friend. She will continue, however, to make her services available to the School part time and for this we are extremely grateful.

During the academic year 1985-86 two new funds were established in memory of Robert Lockett, a member of the 1985 master's class, and James S. Stiel, Sloan Fellows Class of 1980, respectively. The initiatives for these funds were taken by classmates of the deceased alumni.

For the first time in the history of the School we have seen the establishment of reunion gift funds. The classes of 1975 and 1976 under the respective leadership of John Erdman and Mimi Ritter were the pioneers. We expect more similar initiatives in the future.

On the occasion of the retirement of Professor Wallace, Rita O'Brien (Sloan Fellows Class of 1977) took the initiative to spearhead a drive for the Phyllis Wallace Visiting Scholar Fund and the Phyllis Wallace Doctoral Fellows Fund. Plans are in the making for securing the full funding of both these endowments.

Other resource development activities of note include: (a) the receipt of a grant of \$450,000 over three years from Coopers & Lybrand Foundation to encourage our faculty to look at the implications of information technology for the accounting profession--Professors Bitran, Graves, and Zannetos have started exploring this area; (b) a grant of \$250,000 over five years from Bankers Trust to encourage the School's activities in the area of artificial intelligence and banking--Professors Malone and Davis are involved in this area; (c) the receipt of \$100,000 over two years from the Latsis Foundation for scholarships; and (d) generation of support of \$93,750 from Prime Computer and \$25,000 from Analog Devices for Professor Orlin, who has won a Presidential Young Investigator Award for five years.

Discussions are continuing with the American Electronics Association for a program responding to the needs of top managers in the high technology area, and with representatives of banking institutions for a program that addresses the challenging issues of modern information technology.

Finally, relationships are being strengthened with other parts of the Institute for joint resource development projects. The prospects for bringing large amounts of funds in future years are very promising.

The School's efforts in resource development have continued to be greatly facilitated and supported by Professor Samuel A. Goldblith and his successor, Glenn P. Strehle; by the MIT Development Office staff; and by William J. Hecht and his colleagues at the MIT Alumni Association. The Sloan School is most grateful for this continuing spirit of cooperation.

Over the past year, alumni/ae relations have continued to develop strongly. A deep commitment to improve our contacts with and services for our alumni/ae body was made several years ago, and we have been building on that commitment over the years. This year has seen the further strengthening of the Sloan Club, a national organization representing Sloan School master's and PhD program graduates. The Sloan Club now has regional chapters throughout the United States, each with its own regional board whose members put together a wide variety of programs of interest to local alumni/ae. These programs are open to all Sloan School graduates and have realized enthusiastic attendance from alumni/ae of the Sloan Fellows, Senior Executive, Management of Technology, and undergraduate programs. Sloan Club chapters work closely with the local MIT clubs in their area as well, often sponsoring events jointly. The Sloan Club of New York collaborated with New York's Harvard Club this past year in a sell-out fall program featuring a private screening of the film "White Nights." The Sloan Club Board meets three times annually at Sloan to review the progress of its alumni/ae activities and to discuss further ways to better represent and service its constituents and the School.

Yearly reunions are becoming tradition at Sloan. This June over 100 participants returned, including spouses and guests, to attend a series of events one Saturday organized for their enjoyment and education. The afternoon included a mini-symposium by Professors Scott Morton and Malone on artificial intelligence and expert systems followed by a cocktail reception in the Sloan lobby. Saturday evening, a dinner dance was held at the new Boston Embassy Suites Hotel.

The Board of the Society of Sloan Fellows met twice this year at Sloan, in October and February, to discuss ongoing projects. At the time of this writing, they are working very hard on their upcoming triennial symposium scheduled for October at MIT. The topic this year will be "Management in the Nineties."

The School's alumni/ae publication, SLOAN, is published twice a year, Winter and Spring. This year's cover features included a fascinating history of MIT's Endicott House and an interview with Colby Chandler, Chairman and CEO, Eastman Kodak Company.

All told, the School's external relations efforts continue to grow and to afford great mutual benefits through that growth both to the School and to its several external constituencies.

#### STAFF CHANGES, PROMOTIONS, AND VISITORS

At the beginning of the 1985-86 academic year, three faculty members were named to three new professorships at the School. Thomas J. Allen was named the first holder of the Gordon Y. Billard Fund Professorship of Management, a chair established by Mr. Billard, a 1924 graduate of the School. Professor Allen has been working in the area of organizational psychology and management at MIT since 1966 and has focused on the management of research and development; he has been particularly interested in tracking the flow of technical information in a system and the corollary innovations attributable to such information.

Thomas L. Magnanti was named to the George Eastman Professorship of Management Science, a chair made possible by contributions from the Eastman Kodak Company and from two donors who prefer to remain anonymous. Professor Magnanti came to the School in 1971 and has wide-ranging research interests covering a mix of theoretical studies in combinatorial and network optimization, in nonlinear programming and in large-scale systems, as well as applied studies in various aspects of distribution and transportation planning. Professor Magnanti has headed the School's Management Science Area since 1982.

Thomas W. Malone was named as the first Douglas Drane Career Development Associate Professor in Information Technology and Management, a chair which provides support to outstanding scholars working on the frontiers of management science. Professor Malone has been on the management information systems faculty since 1983 and was promoted this year to the rank of Associate Professor. He has focused his research interests toward a wide range of theoretical and methodological approaches related to human problem solving.

Arnoldo C. Hax has been named as the Alfred P. Sloan Professor of Management. The chair was formerly held by Eli Shapiro who retired in 1984. Professor Hax joined our faculty in 1972 and is widely known for his research and writing in the fields of strategic business planning, management control, operations management, and operations research.

Paul A. Samuelson has become the first Gordon Y. Billard Fellow. Dr. Samuelson, Institute Professor and Professor of Economics Emeritus, is one of the world's most renowned economics scholars. Among his many awards and honors was the Alfred Nobel Memorial Prize in Economic Science for 1970, awarded for his contributions to raising the level of scientific analysis in economic theory.

Franco Modigliani was honored with the 1985 Alfred Nobel Memorial Prize in Economics. Dr. Modigliani, an Institute Professor and Professor of Economics and Finance, came to MIT in 1962. His work in the area of financial markets has helped lay the foundation for the entire field of corporate finance. The award citation notes especially his basic research in the "life-cycle" hypothesis to explain savings behavior.

John C. Cox was promoted to the rank of Professor. Professor Cox received a PhD in finance from the University of Pennsylvania in 1975. He has been on the Sloan faculty since 1983 and is widely acclaimed for producing new insights into intertemporal consumption and portfolio theory, contingent claim valuation theory and equilibrium models of markets, and for establishing important new tools for future work.

Two Associate Professors were granted tenure. John S. Carroll received a PhD degree in social psychology from Harvard University in 1973. He joined the Behavioral and Policy Sciences faculty at Sloan in 1983 and has focused his research efforts in the areas of cognitive social psychology, behavioral decision theory, and the psychology of law. His major accomplishments have been concerned with decision making within the criminal justice system on which he published a series of papers reporting on his parole decision research project.

Stephen C. Graves received a PhD in management from the University of Rochester in 1977. Professor Graves has been part of the operations management faculty in the Management Science Area since 1977. He is credited with making pioneering contributions in the areas of automatic warehousing systems, assembly system design, and hierarchical production planning.

Five faculty were promoted to the rank of Associate Professor. Katharine G. Abraham joined the Behavioral and Policy Sciences faculty in 1980. She received a PhD in economics from Harvard University in 1982. Professor Abraham has focused her research on the operation of firms' internal labor markets and she has addressed macro-economic issues related to unemployment.

Terry A. Marsh became a member of the Sloan faculty in 1980. He received a PhD in management from the University of Chicago in 1981. As part of the finance faculty, Professor Marsh has directed his attention to the areas of capital markets, corporate finance, accounting, econometrics, and statistics.

John D.W. Morecroft joined the School's system dynamics faculty in 1979. He holds a PhD in management from MIT (1979). Professor Morecroft has been involved with building system dynamics simulation models to support the analysis and formation of business policy.

Ram T.S. Ramakrishnan joined the School's accounting faculty in 1980. He received a PhD in management from Northwestern University in 1981. Professor Ramakrishnan has directed his research efforts toward the modeling and analysis of accounting issues using information economics.

Thomas W. Malone, mentioned previously, was also promoted to the rank of Associate Professor.

Five new appointments were made to the rank of Assistant Professor. Lode Li, Assistant Professor of Management Science, works in the field of operations management; he received a PhD degree in managerial economics and decision sciences from Northwestern University in 1984.

Lisa M. Lynch, Assistant Professor of Behavioral and Policy Sciences, is working in the field of industrial relations; she received a PhD degree in economics from the London School of Economics in 1983.

Patricia C. O'Brien, Assistant Professor in the Accounting section of the Economics, Finance, and Accounting Area, received a PhD in accounting and econometrics from the Graduate School of Business at the University of Chicago in 1985.

Nancy L. Rose, Assistant Professor of Applied Economics in the Economics, Finance, and Accounting Area, received a PhD in economics from MIT in 1985.

N. Venkatraman, Assistant Professor of Strategy and Policy in the Behavioral and Policy Sciences Area, received a PhD in strategic planning and policy from the Graduate School of Business at the University of Pittsburgh in 1985.

This year Mary P. Rowe began a joint appointment as Adjunct Professor of Management and Special Assistant to the President. In addition to her work on non-adversarial dispute resolution, she taught a Seminar in Negotiation and Conflict Management.

The School welcomed a number of visiting faculty this year. Nicolas Majluf, a Visiting Professor from the Universidad Catolica de Chile, taught Strategic Analysis in the fall and co-taught Advanced Topics in Policy and Strategy in the fall and spring.

Rene M. Stulz, a Visiting Associate Professor from Ohio State University, taught International Managerial Finance in the fall.

Five Visiting Assistant Professors joined us. William T. Dickens, Jr., from the University of California at Berkeley, taught Industrial Relations and Human Resource Management in the spring. Sumantra Ghoshal, a 1985 graduate of our doctoral program, taught International Business Management in the fall and Special Topics in International Management in the spring. Deborah L. Gladstein, from the Amos Tuck School at Dartmouth, taught a section of Managerial Behavior in Organizations in the fall, as well as Interpersonal Dynamics and Management of Groups and a doctoral Seminar in Organizational Studies in the spring. E. Allen Jacobs, from the University of Texas at Austin, taught Energy Economics and Policy in the fall and Managerial Economics in the spring. Stanley B. Zdonik, Jr. from Brown University taught Management Information Technology in the fall.

Visiting Lecturers, Senior Lecturers, and Instructors this year included David Chapman, who lectured in our operations management subjects; Karla Karash, who taught Measurement for Management; Donald Rosenfield, who taught Industrial Project Evaluation; Sheldon Borkin, who co-taught Advanced Computer Systems; Russell W. Olive, who taught New Technical Ventures; and Marc H. Meyer, who co-taught Manufacturing/Technology Interface.

Paul Cashman came as a Visiting Scientist to work with Professor Malone on the Mail Filter Project, one of the School's "Management in the 1990s" research projects.

Five faculty spent all or part of the year on sabbatical leave. Donald R. Lessard, Professor of International Management; Robert S. Pindyck, Professor of Applied Economics; and Richard L. Schmalensee, Professor of Applied Economics, were away for the year. Stuart E. Madnick, Associate Professor of Management Science, was away for the fall; and Eric A. von Hippel, Associate Professor of Management, was away for the spring term. In addition, three faculty spent all or part of the year on professional leave: Katharine G. Abraham, Associate Professor of Industrial Relations, was away for the year; Edgar H. Schein, Sloan Fellows Professor of Management, was away for the spring term; and Terry A. Marsh, Associate Professor of Finance, continued his leave for the year.

Staff promotions included Donna M. Behmer, who was promoted from Assistant Director of Finance and Administration to Director of Finance and Administration; Sandra Anthony, who was promoted from support staff to Coordinator, Program for Senior Executives; Norma Gicka, who was promoted from support staff to Accounting Supervisor; Lucinda Hill, who was promoted from support staff to Master's Program Coordinator; Jacalyn Walker-Sharp, who was promoted from support staff to Coordinator, Management of Technology Program; Mary Anne Brady, who was promoted from support staff to Sponsored Research Staff Administrator.

There were four changes in designation: Ralph Katz, Visiting Associate Professor, became Research Associate; Peter Senge, Assistant Professor, became Research Associate; Miriam Sherburne, Director of Master's Admissions and Counseling, became Master's Program Advisor; Margaret Daniels Tyler, Master's Admissions Coordinator, became Director of Master's Admissions.

Two transfers to the School included Roger A. Samuel, who transferred from the Industrial Liaison Office to serve as Program Manager in the "Management in the 1990s" program; and Patricia White, who transferred from the Plasma Fusion Center to serve as Sponsored Research Staff Administrator in the Center for Computational Research in Economics and Management Science.

Julius Niewiarowski joined the School as a Systems Programmer in our Computer Facility. Sarah Cliffe joined the Sloan Management Review staff as Assistant Managing Editor.

Three new Research Associates joined the School: Patrick Henaff, who received a PhD from the University of Texas at Austin in 1985, joined the staff in the Center for Computational Research in Economics and Management Science; Mark Hunsberger, who received an SM from the Sloan School in 1985, joined the "Management in the 1990s" staff; Ellen S. Quackenbush, who also received an SM from the Sloan School in 1985, joined the staff in the Center for Information Systems Research.

Three of our faculty retired this year: Daniel M. Holland, Professor of Finance (to be reappointed as Senior Lecturer and Assistant to the Provost); Richard D. Robinson, Professor of Management; and Phyllis A. Wallace, Professor of Management.

A number of individuals departed this year. Departures from the faculty included Associate Professors John D.W. Morecroft, Ram T.S. Ramakrishnan, and Walter W. Powell; Assistant Professors David Anderson, Leigh McAlister, and Gordon B. Walker; and Senior Lecturer J. Morrison McInnes. Departures from the Administrative Staff included Loren Cox, Elizabeth Goodman, Anne Wood Lipner, and James Gabbert. Sponsored Research Staff departures included Nancy Hack, Elizabeth Flanagan, Stephen Peters, Martin Shell, and Leigh Sobetzer. Each offered their talents to the School and made important contributions during their stay with us.

With great sorrow, we note the death of two members of the Sloan "family" and faculty. Douglass V. Brown, Alfred P. Sloan Professor of Industrial Management Emeritus, devoted 36 years of service to the Sloan School. Professor Brown played an important role in shaping a variety of union-management relationships as well as in shaping labor law and public policy dealing with the resolution of industrial conflict. He influenced generations of students and was always available to assist his students and his colleagues.

Edwin Kuh gave 31 years of service to the School. He also held a joint appointment with the Department of Economics. Professor Kuh was one of the outstanding pioneers in econometric studies. His work focused on the measurement of the reliability of econometric models in forecasting such functions as production, savings, business cycles, and unemployment. Professor Kuh also served as Director of the MIT Center for Computational Research in Economics and Management Science since its formation in 1978. Professor Kuh's dedication to his profession was matched by his strong commitment to values of fairness and justice in the society at large.

Both Professor Brown and Professor Kuh were dedicated colleagues and we shall miss them deeply.

ABRAHAM J. SIEGEL

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## School of Science

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In the past year during the discussions with department heads, center and laboratory directors and faculty members about the long and short range plans in the School of Science, the Dean's Office has taken the opportunity to review various aspects of education and research, the two primary activities of the School. It is clear that the quality of research in the School of Science remains high and that the educational programs for graduate students and those undergraduates who are science majors are generally very good. However some concerns and areas for improvement have become apparent. These issues are presented below along with actions taken in the past year to deal with some of them.

A School of Science education committee was appointed to examine the science core (Institute) requirements, the science distribution requirements and the laboratory requirement. This examination was undertaken in conjunction with, and as a part of, the Institute-wide evaluation of undergraduate education. The members of the committee were Linda Elkins (student) and Professors Arthur Mattuck, Robert Jaffe, John Southard, Robert Weinberg, and Robert Silbey (Chairman). The committee was charged with dealing with the following questions: (a) do the present core requirements in science and mathematics prepare students adequately for their future education at the Institute; (b) are the subjects comprising the core requirements being taught well and are they coordinated with one another; (c) are the present science distribution requirement subjects fulfilling a useful purpose in the education of undergraduates, especially those outside the School of Science; and (d) does the laboratory requirement provide a useful and general scientific experience? The committee met regularly during the year and a first draft report has been prepared and submitted to the Dean. Their findings and recommendations will be discussed in the coming year within the context of the reports submitted by other Institute committees working on undergraduate education. I wish to express my thanks to the members of this committee for their willingness to examine these issues in great detail.

During the past year, with the encouragement of the Dean, the administrative officers of the departments organized and established an effective School-wide laboratory safety program under the direction of Lydia Snover, Program Coordinator. The program insures that all new (and continuing) laboratory personnel receive appropriate and adequate information about good laboratory safety procedures. This is a very important issue and I am very pleased with the initiative demonstrated by the administrative officers in organizing such an effective program.

Discussions with department heads and faculty members have made clear the concerns in the School of Science about the lack of resources for the financial support of graduate students. Under ideal conditions, graduate students should not have to depend on being supported during the first year as either a teaching assistant or research assistant because most graduate students are not as well prepared to teach during the first year as they are in later years, and all first year students would be better off if they could begin their graduate training without making the early commitment to a particular research project or a particular supervisor that the appointment as a research assistant requires. A high priority item for future fund raising activities in the School is to establish an endowment fund to support first year graduate students.

The School-wide consensus is that two other areas for which funds should be raised are for the support of faculty salaries (endowed chairs) and for the establishment of a School of Science endowment fund to support worthy research projects, particularly for junior faculty members.

In addition to those issues presented above, I feel that there are some others that require serious attention in the near future. Although I am convinced that the educational activities in the School are generally good, I believe that we can and should improve the quality of education provided for our undergraduate and graduate students. We owe these students the very best that we can offer. I also believe that we must do better in attracting minority students to our graduate programs and that it is imperative that we increase the numbers of minority faculty members. I intend to work vigorously to achieve these goals.

## ACADEMIC PROGRAMS

There were 810 undergraduates in the School of Science during the past academic year, an 8.3% increase from the previous year. The number of minority students at the undergraduate level changed as follows:

Blacks:	increased from 12 to 21 (+75%)
Hispanics:	increased from 13 to 23 (+76.9%)
Native Americans:	decreased from 5 to 2 (-60%)
Asian Americans:	increased from 95 to 107 (+13%)

The female undergraduate population increased by 10 percent. Twenty-three percent of the Institute's upperclass undergraduates were enrolled in the School of Science.

Graduate enrollments in science increased from 1,077 in the 1984-1985 academic year to 1,123 in the 1985-1986 academic year. The total enrollment represents 22.7 percent of the graduate student population at MIT. The number of minority students at the graduate level changed as follows:

Blacks:	increased from 14 to 17 (+21.4%)
Hispanics:	decreased from 6 to 4 (-33%)
Native Americans:	increased from 0 to 1 (100%)
Asian Americans:	increased from 2 to 4 (100%)

The number of female graduate students increased by 2.6 percent.

There were 275 faculty members in the School this past year. This represents a slight decrease from the previous year. The undergraduate student-to-faculty ratio was 3 to 1, and the graduate student-to-faculty ratio was 3.8 to 1.

## RESEARCH

The FY'86 volume of the School of Science was approximately \$90,000,000. This represents a 5.6 percent increase from the previous year.

## FACULTY

Numerous honors and awards were received by faculty in the school this past year. The following ones are in addition to those reported by the departments in their individual reports. Professor Robert Silbey of the Department of Chemistry was the recipient of the Science Council Award for excellence in teaching undergraduates. Professor Phillip Sharp, Class of 1941 Professor and Director of the Center for Cancer Research, was one of ten scientists who received the 1986 Gairdner Foundation International Awards, which recognize outstanding contributions in the field of medical science. The 1986 Doherty Professorship in Ocean Engineering was awarded to Professor Renee Fitts of the Department of Applied Biological Sciences. Professor Emeritus Claude E. Shannon, Donner Professor of Science and professor emeritus of mathematics and electrical engineering, received one of three Kyoto Prizes, which reward achievements not covered by the Nobel Prizes. Two Assistant Professors in the Department of Physics, Gabriel Kotliar and John Tonry, were among 90 young scientists of "extraordinary promise" awarded fellowships by the Alfred P. Sloan Foundation.

Effective July 1, 1986 Professor Gregory Petsko of the Department of Chemistry was promoted to Full Professor, and Professor Rick Danheiser also of the Department of Chemistry was awarded tenure.

We mourn the tragic death of Dr. Ronald McNair (Ph.D. in Physics-1977), who died when the Space Shuttle Challenger exploded during a mission. In honor of his memory Building 37, which houses the Center for Space Research, will be named the Ronald E. McNair Building in the fall of 1986. We also were saddened by the death of Professor Phillip Morse of the Department of Physics, whose numerous contributions to MIT included helping to develop the science and practice of operations research, serving as head of the Operations Research Center (1956-1969), and co-founding the Acoustics Laboratory and MIT Computation Center. He was an internationally known scientist who received numerous honors and awards for his outstanding contributions to science.

GENE M. BROWN



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## Department of Applied Biological Sciences

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The year was one of continued transition in terms of the change in emphasis of both the research and educational programs of the Department, reflecting the changes signified by the formal change in its name last year. In addition to consolidation of the graduate degree programs described below, we have been searching for additional new faculty members to replace those who have resigned or retired over the past two years. Individuals are being sought whose backgrounds and interests will complement those of present faculty, and whose areas of expertise will further strengthen the teaching programs as well as the research activities represented in the Department. One new faculty member, Dr. Douglas Youvan, has been appointed, and applicants are being evaluated for the additional positions currently vacant. We expect to fill those positions within the next academic year.

### FACULTY

The past year has been one of significant change with respect to the status of several members of the departmental faculty. Drs. John M. Essigmann and Michael A. Marletta were promoted to the rank of Associate Professor of Toxicology, effective July 1, 1986.

Professor Richard J. Wurtman requested transfer of his appointment to become Professor in the newly formed Department of Brain and Cognitive Sciences, also effective July 1, 1986. Professor Wurtman will continue to hold the concurrent position of Director of the MIT Clinical Research Center.

Professor R. Alan North submitted his resignation, to be effective December 31, 1986, in order to accept a position in the Oregon Health Sciences University, in Portland, Oregon.

Senior Lecturer and Professor Emeritus Paul M. Newberne entered retirement on July 1, 1986. Professor Newberne has accepted a part-time appointment at the Boston University School of Medicine which will allow him to continue certain of his research activities on a limited basis.

Dr. Douglas A. Youvan accepted appointment as Assistant Professor of Applied Biological Sciences, effective July 1, 1986. Dr. Youvan comes to MIT from the Cold Spring Harbor Laboratory, where he has had an active research program dealing with the structure and genetic regulation of the photosynthetic apparatus of the pigmented bacterium *Rhodospseudomonas*. Using molecular biological, physical, and spectroscopic techniques, he has made extraordinary progress in elucidating the structure and function of the photosynthetic apparatus in this organism. This experimental system provides a virtually unique model for studies of photosynthesis which may also be applicable to higher plants. Dr. Youvan received his doctoral training in biophysics at the University of California at Berkeley, and has been a staff scientist at the Cold Spring Harbor Laboratory for approximately five years.

### RESEARCH PROGRAMS

The research programs of the departmental faculty and their colleagues have continued to flourish during the past year, as indicated by the continued increase in research funding received from federal and other sources. The major areas of research activity continue to be in biotechnology, biochemical engineering, and toxicology. Further information about the specific research programs of each faculty member is available in the *Faculty Research Summaries*, which are available in the Department headquarters, Room 16-333.

### EDUCATIONAL PROGRAMS

During this academic year, undergraduate majors enrolled in the Applied Biology program (Course VIIB) numbered 39 during the Fall term, and 36 in the Spring term. In addition, there was strong participation of faculty and staff in UROP projects for undergraduates. In all, a total of 14 faculty members supervised research projects for an average of 29 students during each of the academic terms. Other interactions with undergraduates included participation as freshman advisors and premedical advisors.

As the research emphasis as well as the composition of the faculty has continued to change over the past years, extensive revisions have also been made in the curriculum for graduate study leading to degrees in the Department. In the 1985-86 academic year, the consolidation of specialized degree programs into a single departmental degree program has been completed. As of the entering class of the Fall, 1986 term, all graduate students entering the Department will receive degrees in either Applied Biological Sciences or in Biochemical Engineering, the latter program having been in existence for many years and successfully offered jointly with the Departments of Chemical Engineering and Biology. Fields of specialization currently offered within the Applied Biological Sciences program include biotechnology, biochemical engineering, and toxicology.

The number of graduate students enrolled as SM or PhD candidates in the Department numbered 114 during the Fall term and 105 during the Spring term. Doctoral degrees were awarded to 16 students, and SM degrees to 11.

### HONORS AND AWARDS

Honors and awards were accorded to several members of the faculty and students of the Department during the past year.

Professor Daniel I.C. Wang, who holds a joint appointment as Professor of Biochemical Engineering in the Department of Chemical Engineering, was elected to the National Academy of Engineering, in recognition of his contributions to fermentation technology and more generally to the field of bioengineering.

Professor Robert S. Langer received the Food, Pharmaceutical, and Bioengineering Award of the American Institute of Chemical Engineers in recognition of his pioneering contributions to the development of drug delivery systems for the effective delivery of large molecular weight drugs from synthetic polymeric matrices and for more general contributions to the drug delivery and controlled release fields. Professor Langer was among the youngest recipients of this prestigious award accorded to Chemical Engineers.

Professor Marcus Karel was the recipient of the Nicholas Appert Award of the Institute of Food Technologists. The Appert Award, named for the early 19th century scientist whose invention of food-preservation techniques led to the modern food canning technology, honors Professor Karel for his preeminence in and contributions to the field of food technology.

Professor Marie Chow was a corecipient of the AAAS-Newcomb Cleveland Prize, which is awarded to the author of an outstanding paper published in the journal *Science* for the year 1985. In this paper, entitled "Three dimensional structure of poliovirus at 2.9 Å resolution", Professor Chow and her coauthors described the structure of the virus on the basis of high-resolution x-ray crystallography to a level of detail never before achieved. Their characterization of the viral structure will have major impacts on the further elucidation of the ways in which viruses are assembled, how they are held together, and how they are taken apart when they infect cells.

Honors were also accorded to students in the Department in the form of fellowships and awards recognizing their research contributions. In the former category Mary Chang, a first year graduate student working with Professor Robert Lees, was the recipient of an Ida M. Green fellowship. The Hugh Hampton Young Memorial Fellowship was awarded to Cato Lurencin, a graduate student in the Department and in the HST program as well. Mr. Laurencin is carrying out his doctoral thesis research in the laboratory of Professor Robert Langer. Two students were recipients of fellowships from the Whitaker Health Sciences Fund. They were Mr. Hugh Barton, working with Professor Michael Marletta, and Mr. Tanious Abu-Nader working with Professor Richard Wurtman.

The first recipient of the newly established Bernard E. Proctor Award for excellence in research by an undergraduate (UROP) student was Ms. Irene Griff, who conducted her project with Professor Marletta. The project was entitled "Carcinogen Binding Protein Purification," and the prize includes an expense-paid trip to a domestic scientific meeting.

The Miriam M. Znaty Research Award has also been established by the Department to recognize excellence in research by graduate students in the Department. The Prize was established in memory of the late Ms. Znaty, who was an inspiring young colleague and dedicated researcher. The first award will be made in September, 1986, on the basis of excellence in doctoral thesis research as judged by the departmental committee on graduate students. The prize carries a cash award in addition to expenses for presentation of the results at an appropriate professional meeting.

GERALD N. WOGAN

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## Department of Biology

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### INTRODUCTION

During this academic year the department has adjusted to its new administration after many years under the capable leadership of Dr. Gene Brown. The year saw further progress in the department's ventures in developmental and neurobiology.

### EDUCATIONAL ACTIVITIES

#### Undergraduate Program

In the past year, the Department saw its highest undergraduate enrollment in a decade, with 272 undergraduates registered as Life Sciences majors. Of these, 106 received the degree of Bachelor of Sciences in Life Sciences: 66 in the regular Course VII Program, 27 in the VII-A Program, and 13 in the VII-B Program. Most of these graduates will attend either medical or graduate school.

This spring a new subject 7.09 Cellular Neurobiology was taught for the first time. Teaching of this subject was made possible by a recent appointment in Biology and two joint appointments between Biology and Whitaker College which represent the continuing expansion of our commitment to the development of neurobiology at MIT.

The Committee on Curricula has approved two new undergraduate subjects to be offered for the first time in the 1986-1987 academic year. These are 7.55J Reproductive Biology, intended primarily as an elective course to introduce non-majors to the concepts and discoveries of cell and molecular biology which affect the ability of the human race to influence its own reproduction. The other, 7.52J Biotechnology of Mammalian Cells, will be an upperclass elective for majors in Biology, Chemical Engineering, and Applied Biological Sciences. The subject will introduce students to the biological and bioengineering principles involved in producing mammalian proteins by in vitro culture techniques.

The recipient of the John L. Asinari Award for 1985-1986 for outstanding research by undergraduates in Life Sciences was Saechin Kim, a senior, for a research project done in the laboratory of Professor Frank Solomon. Honorable mention went to James H. Koenig, a junior (faculty supervisor, Professor Vernon M. Ingram).

#### Graduate Program

During the period from July 1, 1985, to June 30, 1986, 19 Ph.D. degrees were awarded in the Department and three in the Joint Program in Biological Oceanography with the Woods Hole Oceanographic Institute. The maximum number of Ph.D. candidates registered in the Department in 1985-1986 was 143, with another 17 in the Joint Program. The entering class, including those in the Joint Program, in 1985 was 29 and the class arriving in September, 1986, will again be 29. The cell biology course was expanded to a semester pair of subjects (7.60 and 7.61) each of which was taken by a large number of students. The new curriculum was judged a success by both students and faculty.

A new subject, 7.66 Molecular Neurobiology, was taught for the first time.

Discussions have continued on the structure of a graduate program in molecular and cellular neurobiology to be joint between the Biology and Brain Sciences departments. 7.66 is the first new course introduced which will be a part of this program.

### RESEARCH

The research activities of the Department are in the areas of biochemistry, genetics, microbiology, cell and developmental biology, immunology, neurobiology, and virology. Individual research projects are described in the publication, Biology Research Summaries, available in the Biology Headquarters Office (56-511).

### PERSONNEL

During the past year, Dr. Richard C. Mulligan was promoted to Associate Professor with tenure, and Drs. H. Robert Horvitz, Frank Solomon, Alexander J. Varshavsky, and Graham C. Walker were promoted to Full Professor, effective July 1, 1986.

Dr. Bernard Gould has relinquished his role as departmental undergraduate advisor after many years of yeoman service. We shall miss his contributions. His responsibilities will be taken over by Dr. Graham Walker.

Dr. Eugene Bell retired at the end of February.

Professors Herman Eisen and Alexander Varshavsky were on sabbatical leave during the fall term, 1985. Both remained in Cambridge: Dr. Eisen to write a textbook and Dr. Varshavsky to devote full time to a research project in his laboratory here.

Dr. Donald C. Rio has accepted the position of Assistant Professor to be joint with the Department and the Whitehead Institute for Biomedical Research, and plans to begin his appointment in July of 1987. Dr. Rio received the Bachelor's degree in 1979 from the University of Colorado, Boulder, and the Ph.D. Degree in Biochemistry from the University of California, Berkeley, in 1983. Since December 1983 he has been a Postdoctoral Fellow in the Department of Biochemistry at the University of California, Berkeley. Dr. Rio's research interests are in the area of the regulation of gene expression during development in higher eukaryotes.

Dr. Thereza Imanishi-Kari will leave on July 1, 1986 to join the faculty at Tufts Medical School.

#### Honors and Awards to the Faculty

It is a pleasure to report the following honors and awards received by various faculty members in the past year:

Dr. Steven J. Burden has been selected as the first holder of the Thomas D. and Virginia W. Cabot Career Development Professorship, to be effective July 1, 1986. This chair, established to recognize excellence in teaching and research by young faculty members, was awarded to Dr. Burden on the basis of his outstanding work on the mechanisms of regulation and function of the components involved in nerve-muscle synapses.

Dr. H. Robert Horvitz was a co-winner (with Dr. Walter Gehring) of the Warren Triennial Prize of the Massachusetts General Hospital, for his pioneering studies in developmental biology and his contribution to the area of homeotic genes. Dr. Horvitz also received the W. Alden Spencer Award of the College of Physicians and Surgeons of Columbia University for his outstanding contributions to research in neurobiology.

Dr. Monty Krieger was chosen to be the first holder of the Latham Family Career Development Professorship for his outstanding contributions to education and scholarship in biochemistry, especially his work in cholesterol metabolism and the role of lipoproteins.

Dr. Salvador E. Luria was honored at the Third Annual Whitehead Symposium in October.

Dr. Paul T. Matsudaira received a Pew Scholars Award in Biomedical Sciences.

Both Sheldon Penman and Susumu Tonegawa were elected to the National Academy of Sciences; Dr. Tonegawa also received the Bristol-Myers Award this year.

Dr. David Raulet was selected as the first holder of the Robert A. Swanson Assistant Professorship of Life Sciences effective July 1, 1986. He was chosen for his outstanding work in immunology, in particular, the expression of genes for the T cell receptor during development of the immune system.

Dr. Phillip A. Sharp was named as the first holder of the Class of '41 Chair for his outstanding contributions to education and scholarship in cellular and molecular biology; in addition, Dr. Sharp was awarded the General Motors Cancer Research Prize this year.

Dr. Frank Solomon won the MIT Graduate Teaching Award for the second time (he first received this award in 1984).

#### VISITING COMMITTEE

The departmental visiting committee under the chairmanship of Dr. David I. Kosowsky visited MIT on May 22-23, 1986. They indicated that they feel that the department is in strong intellectual shape. However, they agree with the departmental administration that the physical plant represents a significant problem, which needs a radical solution. They advocated the acquisition of a new or renovated building to house the members of the department currently in buildings 16 and 56.

MAURICE S. FOX  
RICHARD O. HYNES

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## Department of Chemistry

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Bachelor of Science degrees in Chemistry were awarded this year to 42 undergraduates. Most of the graduates will be attending graduate school in chemistry, medicine, or related disciplines, or have taken industrial employment. The Masters of Science degree was awarded to 2 people. A total of 38 Ph.D. degrees were awarded: 9 in September; 13 in February; 16 in June. To date 1821 Ph.D. degrees and 405 Masters degrees have been awarded by the Department.

### PERSONNEL

Professor Klaus Biemann received the 1986 Frank H. Field and Joe L. Franklin Award for Outstanding Achievement in Mass Spectrometry awarded by the American Chemical Society.

Professor Sylvia Ceyer received an Alfred P. Sloan Award and was appointed to the Class of 1943 Career Development Chair.

Professor Rick Danheiser finished his term as Firmenich Career Development Professor in Natural Products Chemistry and was succeeded in this development chair by Professor Stephen Buchwald.

Professor Stephen Lippard was elected to the American Academy of Arts and Sciences.

Professor K. Barry Sharpless was awarded the first Janssen Prize in Natural Products Chemistry, to be awarded biennially to a chemist under the age of fifty. Professor Sharpless received the award in May at the meeting of the Belgian Chemical Society in Brussels. Professor Sharpless received the Arthur C. Cope Scholar Award given by the American Chemical Society.

Professor Gardner Swain became an emeritus member of the faculty after a distinguished career that started in 1947 at MIT.

### ACTIVITIES OF THE DEPARTMENT

The Department was privileged to host Dr. T.Y. Shen as the T.Y. Shen Visiting Professor in Medicinal Chemistry.

CHRISTOPHER T. WALSH

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## Department of Earth, Atmospheric, and Planetary Sciences

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### FACULTY AND RESEARCH STAFF

On July 1, 1985, Professor James Elliot was promoted to Full Professor, and Professors Paola Rizzoli and Kerry Emanuel were promoted to Associate Professor. Also on that date, two new Assistant Professors were appointed - Professors Earle Williams and Jack Wisdom. Two of our research scientists, Drs. Robert King and Christopher Measures, were promoted to Principal Research Scientist on July 1, 1985. Professor Charles Eriksen resigned, and Dr. Joseph Walsh took early retirement from the Department on June 30, 1986. Professor Barry Parsons also resigned on that date, to take up a position as Reader at Oxford University. On July 1, 1986, Professor John Southard was promoted to Full Professor, and Professor Marcia McNutt to Associate Professor. Also on July 1, 1986, Dr. Peter Molnar resigned as Full Professor to become Senior Research Scientist.

### Honors

In January, 1986, a new Cecil and Ida Green Development Professorship in Oceanography was created, for awarding to junior faculty for terms of three years, and Assistant Professor William Young was the first recipient. Also in 1986, Professor Kerry Emanuel received the distinguished Meisinger Award from the American Meteorological Society, and Professor Theodore Madden was the honored recipient of the Society of Exploration Geophysicists' Reginald Fessenden Award.

### ENROLLMENT

Our graduate enrollment for the academic year just ended was 185, with 50 being Joint Program students at Woods Hole Oceanographic Institution. The undergraduate enrollment was 34. The annual geology field camp in Nevada and the biannual astronomy field camp in Arizona took place in January, 1986.

### RESEARCH

#### Geology/Geochemistry

Professor Clark Burchfiel has field research projects in China, Sweden, Bolivia, western United States and Greece. Several months were spent in study of Greece and Bulgaria where crustal extension began in late Eocene time and has progressed to the present. Extension has been contemporaneous with and in proximity to convergence in the Hellenide Mountain belt. Late Eocene extension in southern Bulgaria may have been contemporaneous with convergence both to the north and south, suggesting shallow level coastal gravitational collapse may have played an important role.

Continuing research on the spectroscopy of iron-bearing minerals by Professor Roger G. Burns has led him to propose that two additional mineral assemblages might be present in the weathered rocks seen on the surface of Mars. They are red-brown iddingsite and hisingerite formed by hydrothermal alteration of iron-rich olivine in basalts poured onto the surface of Mars, and a variety of basic ferric sulfate minerals (jarosite, copiapite, botryogen) occurring in gossans capping oxidized sulfide ore deposits on Mars. The presence of these minerals would indicate that the permafrost beneath vast areas of Mars' surface is acidic.

Based on geochemical studies of lavas from volcanoes in the southern Andes, Professor Fred Frey's research group has defined the petrogenetic evolution of single volcanoes and the role of continental crust, subducted oceanic crust, oceanic asthenosphere and continental lithosphere in causing systematic inter-volcano geochemical differences which vary with latitude.

As part of his continuing study of subduction zone volcanism, Professor Tim Grove has determined the magmatic processes which control the development of andesitic rock series. Studies reaffirm that andesites are not primary magmas, but are produced by crustal level fractionation from mantle-derived basalts. The most important controls on the type of andesite trend found in a convergent margin setting are the pressure of differentiation, the water content of the magma and the assimilation of silicic crustal material by the parent magma. In young island arcs where the crust is thin and subduction rates are fast, a distinctive low pressure andesite series develops. In island arc environments where the crust is thicker and subduction rates are slower, a high pressure calc-alkaline trend develops.

Professor Stan Hart has continued to delineate the large-scale Sr, Nd, and Pb isotopic anomaly in the southern hemisphere mantle. With few exceptions, this "DUPAL" anomaly is indeed restricted to Southern Latitudes; limited data from polar regions (North and South) shows these also to be anomalous, but with a signature which is complementary and inverse to the DUPAL signature. At least one component of the DUPAL anomaly has been traced to delaminated subcontinental lithosphere; another component probably represents recycled oceanic crust and sediment.

The thermal structure and tectonic evolution of the High Himalayas in Nepal and India have been the focus of much of Professor Kip Hodges' research over the past year. Results thus far indicate that intra-continental subduction processes 10-20 million years ago led to lower crustal melting which effectively buffered temperature over a 10 km thick section of the Himalayan orogen.

Individual sub-calcic garnet crystals from Finsch and Kimberley diamonds, kimberlite heavy mineral concentrate, and from diamondiferous harzburgite from Siberia have been analyzed by Dr. Nobu Shimizu for rare earth elements, Sc, Ti and Zr with the ion microprobe. The abundances and abundance ratios of the trace elements strongly suggest that the garnets and thus associated diamonds are of sub-solidus (i.e., metamorphic) origin, providing a strong support for the existence of "cold" continental lithosphere in the early history of the earth.

Professor John Southard has continued his laboratory studies of the physics of sedimentary processes. By a new technique for measuring the distribution of jump lengths in sand movement by wind, he has placed constraints on the physics of saltating sand grains and has developed a new model for the dynamics of wind ripples.

### Geophysics

Dr. Vernon Cormier has implemented a technique for connecting 2- and 3-D structure with 1-D or radially symmetric earth structure for use with asymptotic methods of synthesizing seismic body waves. Future applications include the prediction of the multipathing and shadowing of body waves occurring within descending lithospheric slabs and prediction of pulse complexity of body waves interacting with heterogeneities at the base of the mantle.

Professor Gregory Duckworth has developed inversion procedures to estimate under-ice surface scattering parameters and effective attenuation in the sea-bed of the Arctic Ocean using acoustic data from explosions. For the same region, he has developed an acoustic ice-floe tracking system capable of measuring ice drift motions due to internal waves. These measurements have shown that internal wave activity in the upper Arctic Ocean is ten times less energetic than in the main thermocline of temperate oceans.

Professor Brian Evans has investigated solution transfer processes in granular quartz and halite aggregates. In situ observations of crack healing in single crystals of halite are useful in identifying transport paths and in constraining solution transfer kinetics. Both minerals show considerable similarity to sintering processes in metals and ceramics.

Professor Thomas Jordan has been focussing his research on (1) the seismological study of deep earth structure, (2) western U.S. deformation using space-geodetic techniques, and (3) techniques for the statistical description and analysis of seafloor morphology. Particularly exciting results have emerged from tomographic images of the core mantle interface constructed from PKP travel times. These reveal large-scale structures in the vicinity of the interface which are interpreted as variations in the thickness of a chemical boundary layer. According to their hypothesis, this chemical boundary layer plays a role analogous to the continents on the earth's outer surface.

In his core motion studies, Professor Ted Madden is attempting to distinguish between convected features (westward drift) and wave propagation phenomena by examining the time variations of the velocities inferred.

Professor Marcia McNutt has developed a new technique for using variations in the position of the marine equipotential surface as measured by satellite altimeters to separate the effects of volcanic topography loading the surface of the lithosphere from mass inhomogeneities loading the plate from below. Using this new technique, she has been able to constrain the thermal and mechanical structure of the oceanic lithosphere in regions of hot-spot volcanism and establish the necessity of invoking convectively-maintained high temperatures in the thermal boundary layer beneath the lithosphere.

Professor Peter Molnar spent three months in Tibet studying the Tertiary and Quaternary tectonics of that area. The discovery of folded Tertiary rocks within the plateau, folded late Tertiary and Quaternary rocks in north central Tibet, and active reverse faulting on the north edge indicates that the plateau formed and continues to grow by crustal shortening within southern Asia, not by underthrusting of India beneath southern Asia. The active tectonics within Tibet are dominated by normal faulting in the South and strike-slip faulting in excess of 1 cm/yr in the north, allowing eastward extrusion of Tibet.

Dr. Steven Roecker has determined the three-dimensional seismic wave velocity structure beneath the island of Taiwan. The most noteworthy result of this investigation is the discovery of subducted continental shelf to depths in excess of 50 km.

Professor Leigh Royden has been investigating the dynamics of subduction in the Apennine and Carpathian orogenic belts by examining the deflection of the subducted slab beneath the foredeep basin and in front of the thrust belt. The change in plate deflection through time in these recently active belts should yield information about the nature and magnitude of the forces acting on the subducted slab, and how they change following the termination of convergence and subduction.

Professor Gene Simmons has continued to work on the role of microcracks in the transport and/or retention of uranium and thorium in rocks. In addition, he has used gravity and other data in central New Hampshire to relate earthquakes to surface faults.

Professor Sean Solomon and his students have been applying waveform inversion techniques to determine precise source parameters of earthquakes along mid-ocean ridges and transforms. They find that large ridge crest earthquakes are confined to the inner floor of the median valley, a result that supports lithospheric necking models for the origin of median valley topography. The maximum depth of faulting shoals with local spreading rate, indicating a dependence on spreading rate of the characteristic time interval between major episodes of crustal magma injection.

Professor M. Nafi Toksoz<sup>II</sup> has developed seismic scattering tomography for applications to petroleum reservoir delineation and for mapping heterogeneities of the earth's lithosphere. The method has been tested with ultrasonic laboratory data and is being applied to earth using seismic data from wells and from the surface.

### Meteorology

Professor Randall Dole has performed observational analyses demonstrating that major cases of atmospheric persistence are associated with a relatively small number of recurrent large-scale flow patterns. These flow patterns are related to major anomalies in surface temperatures and significant shifts in the locations of maximum storm activity over the Northern Hemisphere.

Professor Kerry Emanuel has been working on a nonlinear air-sea interaction theory for the development and maintenance of tropical cyclones and has engaged in experimental and theoretical research on the mechanism of explosive extratropical cyclogenesis.

Dr. Bruce Fegley has continued studies of the chemistry of the deep atmospheres of Jupiter, Saturn, Uranus, and Neptune. His calculations predict that the atmospheres of Uranus and Neptune are qualitatively different from Jupiter and Saturn. In particular, aqueous cloud condensation occurs at or near the critical point of water. Also, methane ( $\text{CH}_4$ ) and hydrogen ( $\text{H}_2$ ) are important solutes in the aqueous clouds, while ammonia ( $\text{NH}_3$ ) is the only important solute in water clouds on Jupiter and Saturn.

Professor Richard Lindzen is studying aspects of dynamic meteorology ranging from the basic mechanism of shear instability to the reasons for the 100 k year cycles in glaciation. Most recently, he has developed simple models for the air-sea interaction over the tropical oceans, for the generation of planetary scale transient disturbances in the atmosphere, and for explaining why the Pole-Equator temperature difference is what it is.

Professor Edward Lorenz has been investigating the existence of a "slow manifold" - a postulated family of atmospheric states which are devoid of rapid oscillations - by means of a mathematical model. The model atmosphere is found to possess an invariant manifold which has some of the desired properties, but is not unequivocally slow.

Professor Reginald Newell has found that the total atmospheric ozone in a vertical column decreased substantially after the 1982 El Chichón volcanic eruption. The associated increase of ultraviolet reaching the ground and the concomitant increase of atmospheric water vapor in the tropics accompanying the 1982-83 El Niño is thought to have reduced significantly the global build-up of atmospheric methane, thereby providing another example of the complex coupling between atmospheric trace constituents.

Professor Ronald Prinn has determined the global-average concentration of the atmosphere's major oxidizer of the OH radical to be 820,000 per cubic centimeter. This value, obtained by titration using six years of global  $\text{CH}_3\text{CCl}_3$  measurements, is the most accurate determination of this quantity yet obtained.

Professor Peter Stone and his colleagues at NASA completed a study of how climate evolves in response to changes in the amount of carbon dioxide in the atmosphere. The results show that the initial climate changes are not indicative of the ultimate changes. Thus the modest climate changes detected in the past century are no guarantee that there will not be substantial climate changes in the next century.



Professor Earle Williams has been investigating the anomalous polarity of shallow thunderclouds observed in the Genesis of Atlantic Lows Experiments and the structure of lightning with the MIT radars.

### Oceanography

Professor Ed Boyle has used fossil chemical measurements to discover significantly reduced formation of North Atlantic Deep Water (NADW) 10,000 years ago. This deepwater reduction is coincident with a marked surface cooling event seen in Greenland glaciers, North Atlantic surface waters, and European pollen. The evidence implies a tight coupling between NADW formation and the position of the North Atlantic polar front; plausibly this relationship is causal.

This year Professor John Edmond extended his hot spring work to a slow-spreading ridge (Mid-Atlantic between 22 and 26 N) for the first time. Two enormous hot spring fields were found in depths of about 3600 meters, definitely on the scale of mined ore deposits on land. Their temperatures (350 C) and solution chemistries are almost identical to what we have seen at numerous locations on the EPR. There is no evidence for reaction with a deep-seated magma chamber (6 km), and given the size of the deposits (order 5 million tonnes), they cannot be "anomalous".

Professor Glenn Flierl has continued a study of the nature of eddying motions in geophysical fluid flows, demonstrating constraints which must apply if the velocities are to decay rapidly in the far field of the eddy. Several new and more general structures of this type were found. He has completed a numerical study of the growth of waves on a jet to large amplitude, and determined the role of the earth's rotation in altering the amplitudes and structures of the meandering jet. An analytical study aimed at explaining the states observed in the studies has been started, and proves that the earth's rotation can lead to wave-like meanders rather than Von Karman vortex street structures formed in non-rotating flows.

In collaboration with T.L. Ku at USC, Dr. Christopher Measures has made the first combined measurements of  $^{10}\text{Be}$  and  $^9\text{Be}$  in seawater samples collected from three areas of the Pacific Ocean. These measurements combined with others planned for the Atlantic will be used to define the oceanographic regimes within which dating with the 1.5 million year half life  $^{10}\text{Be}$  isotope are valid.

Professor Barry Parsons, together with colleagues at MIT and Lamont-Doherty Geological Observatory, has conducted a shipboard investigation of the pattern of lineated anomalies in the Central Pacific Ocean observed in gravity derived from SEASAT altimeter data. The alignment of the gravity anomalies with the direction of motion of the Pacific plate, and their growth, together with associated depth anomalies, over very young seafloor, can be explained in terms of the development of small-scale convection beneath the cooling oceanic lithosphere. Such an explanation requires viscosities beneath young oceanic lithosphere considerably smaller than the value determined from studies of post-glacial rebound.

Professor Paola Rizzoli has continued her work on coherent structures using a highly nonlinear, localized wave model for atmospheric blocking. She is currently testing the predictions of the theory against meteorological data. She has also begun an extensive study for the assimilation of altimetric and tomographic data in models both of the ocean general circulation and of the Gulf Stream system. The first data to be used will be given by two tomographic experiments of SYNOP (Synoptic Ocean Prediction of the Gulf Stream).

Professor Carl Wunsch and his colleagues are using observations of chemical tracers in the ocean to infer patterns of flow and mixing. The work involves 'inverting' such observations in a time-evolving spatially inhomogeneous fluid flow through the use of models, both analytical and numerical. Methods adopted from both inverse and regularization techniques have been successfully employed.

Professor William Young is currently working on the stability of ocean fronts. Besides being an important problem in its own right, it serves to illustrate the fundamental mechanism of shear flow instability.

### Planetary Sciences

Professor Charles Counselman's group uses portable equipment which receives radio signals from satellites to measure regional displacements of the earth's crust. Accuracy of 1 part in  $10^7$  has now been demonstrated, by comparison with satellite laser ranging measurements in southern California.

Professor Jim Elliot has discovered a companion ring to the delta ring of Uranus from the stellar occultation data obtained from Cerro Tololo Observatory and the McDonald Observatory. Lying adjacent to the inner edge of the delta ring, the companion ring has an observed optical depth of 0.04 and a width of 10 km. He is comparing this and other ground-based results for the rings with the data obtained by the Voyager spacecraft during its recent encounter with the Uranian system.

Dr. Richard French has analyzed earth-based and Voyager 2 observations of the Uranian rings to determine their orbital characteristics and to infer the internal structure of Uranus itself.

Professor David Jewitt has discovered that charge coupled device photometers can be used to obtain direct measurements of cometary nuclei. Accessible properties include the nucleus size, shape and rotation period. He successfully predicted the size and potato shape of the nucleus of Comet Halley, a year before the recent spacecraft encounters.

Professor Gordon Pettengill continues his heavy involvement as Principal Investigator in the Venus Radar Mapping (Magellan) mission. In support of this work he is analyzing data obtained by the Soviets, as well as earth-based radiometric observations obtained from the Very Large Array in the US.

Professor Jack Wisdom has been using the Digital Orrery to study the long-term evolution of the solar system. The best analytic theories of the motion of the Jovian planets have been shown to have serious deficiencies. Pluto has significant orbital variations on timescales of 100 million years as a consequence of a previously unknown commensurability among the fundamental frequencies of the solar system.

Dr. Robert King is using laser ranging observations of the moon to study variations in the earth's rotation. Essentially all of the observed variation on time scales of a few days to a year can be explained by tidally-induced changes in the earth's moment of inertia, and exchange of angular momentum between the atmosphere and solid earth.

#### Geophysics Field Camp

The following results of the January 1985 geophysics field camp were produced during the academic year 1985-86:

Geophysical measurements made largely by MIT undergraduates and teaching assistants, with guidance from T. Madden and P. Molnar, provide evidence for low angle normal faulting beneath Panamint Valley, California, and the area west of it. Since most active normal faults seem to dip steeply, and only inactive faults that have been deeply exhumed indicate gentle dips, these results may be the best evidence showing active normal faulting on very gently dipping planes, at shallow depths. The area west of Panamint Valley apparently was in contact with the Panamint range to the east, and northwestward slip on a plane dipping less than 5 degrees west opened the Valley.

WILLIAM F. BRACE

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## Department of Mathematics

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### ACADEMIC PROGRAM

During the 1985-86 year there were 200 undergraduates majoring in mathematics and 126 graduate students. Of the undergraduate majors, 167 were registered for the general mathematics degree (XVIII), and 33 for the new mathematics with computer science degree (XVIII-C). The Bachelor of Science was awarded to 65 students, including nine second majors. There were five recipients of the Master of Science, three in applied mathematics and two in pure mathematics. Of the 19 recipients of the Doctor of Philosophy in mathematics, 15 were in pure mathematics and four in applied mathematics.

New textbooks were adopted this year for the calculus and the differential equations courses, subjects taken by virtually all students. This necessitated remaking all the syllabi, and some changes in emphasis and content resulted. One consequence is that differential equations now includes an introduction to Fourier series, a subject of great importance in physics and engineering. Also, the reading now includes some historical material, which should fit in well with the renewed interest in a humanities core at MIT.

Pedagogically, we are experimenting in these core service courses with giving students a completely worked collection of homework problems; the hope is that having solutions conveniently available to serve as a source of hints and as models of style will encourage students to put more effort into their daily homework practice. So far, results are somewhat mixed.

There is considerable discussion at MIT about the core science and engineering departments. Discussions with various departments will be held during the summer of 1986, with reference to further possible long-range planning and revision.

An outstanding curricular success has been Professor Gilbert Strang's new course 18.085-18.086 Mathematical Methods for Engineers. The subject matter is novel, emphasizing the analogies between discrete and continuous linear models; optimization under constraints is an important part of 18.085. The total enrollment this year for 18.085 was 142, compared with 73 last year. It is expected that this subject will for some of the engineering departments replace the older and more traditional advanced calculus (18.075-18.076). Professor Strang has written a textbook, Introduction to Applied Mathematics to accompany the course.

### FACULTY

Joining the faculty next year will be Professor of Pure Mathematics Haynes Miller who currently holds appointments at the University of Washington and the University of Notre Dame. His field is algebraic topology.

Associate Professors David Jerison, F. Thomson Leighton and Rodolfo Rosales were promoted to Associate Professor with Tenure.

Assistant Professors David Anick, Anders Björner, and William Goldman were promoted to Associate Professor.

The Department has appointed two new Assistant Professors. They are Ali Nadim (fluid dynamics) and Luis Casian (lie groups).

Applied Mathematics Instructors Mark Haiman, Er-Cheng Tsai, and Stéphane Zaleski were promoted to Assistant Professor.

Faculty on leave during the year were: Baruch Awerbuch (fall), David Benney (fall), Hung Cheng (fall), Daniel Freedman (fall, France), George Lusztig (year, Italy), Richard Melrose (fall), Daniel Quillen (year, Oxford), David Shmoys (spring, MSRI), Michael Sipser (year, MSRI and Berkeley), Richard Stanley (spring, California Institute of Technology), Harold Stark (spring, UCSD), Gunther Uhlmann (year, University of Washington), Michele Vergne (year, CNRS, France).

Associate Professor K.K. Tung has resigned to accept a professorship at Clarkson University. Assistant Professors William Goldman and Gunther Uhlmann have resigned to accept professorships at the University of Maryland and the University of Washington respectively.

Visiting the Department this year were: Melvyn Berger (University of Massachusetts, Amherst), Haim Brezis (Université Pierre et Marie Curie, Paris), Persi Diaconis (Stanford University), Emanuel Dror Farjoun (Hebrew University of Jerusalem), Martha Smith (University of Texas at Austin).

Professor Sigurdur Helgason will succeed Professor Nesmith Ankeny as Chairman of the Graduate Committee. Professor Ankeny has served in this position for the last four years, and is owed a debt of thanks by the Department. Professor Willem Malkus will continue as Chairman of the Applied Mathematics Committee, Professor Franklin Peterson as Chairman of the Pure Mathematics Committee, Professor David Vogan as Chairman of the Undergraduate Mathematics Committee, and Professor James Munkres as Chairman of Advisors.

#### FACULTY HONORS AND AWARDS

Professor Gilbert Strang received the Graduate Student Council Teaching Award for Mathematics.

Professor Victor Kač<sup>V</sup> was named a Guggenheim Fellow.

Assistant Professor Nicholas Trefethen received a Presidential Young Investigator Award from the National Science Foundation.

Professor Kenneth Hoffman will receive on July 23 an award from the Society for Industrial and Applied Mathematics (SIAM) in recognition of his efforts in the planning of a national mathematical sciences policy and the writing of the David Report. Professor Hoffman played also a key role in the establishment by the U.S. Congress this April of National Mathematics Awareness Week.

#### STUDENTS

Two graduate students, Gunther Ziegler and Angelo Vistoli, were selected by a national committee to receive Alfred P. Sloan Doctoral Dissertation Fellowships.

The annual Jon A. Bucsela Prize, given by the Mathematics Department in recognition of distinguished scholastic achievement, professional promise and enthusiasm for mathematics, was awarded to senior undergraduates Lee Newberg and Haw-min Lu.

Avrim Blum, a junior in mathematics, was the first place winner this spring in the New York University Courant Institute Prize for mathematical talent. He won the prize for an original paper he wrote covering random walks on the circle.

ARTHUR P. MATTUCK

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## Department of Physics

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In spite of financial stringencies during the past year, all major research programs in the Department have remained active and some important new initiatives have been started, as described in the detailed accounts later in this report. The Department has continued to address the challenge it faces as a major component of the MIT educational program.

The members of the Physics Department continue to provide leadership for the major MIT interdepartmental laboratories. At present the Directors of the Laboratory for Nuclear Science, Bates Linear Accelerator (BLA), Center for Materials Science and Engineering, National Magnet Laboratory, Spectroscopy Laboratory, and Plasma Fusion Center are members of the Physics Department.

In 1985-1986 the total number of Faculty was 90. Stanley Kowalski was appointed as Professor. During the year the following members of the Faculty received promotions: to Professor, Alan Guth; to Associate Professor, Edward Farhi and Ralph McNutt. Four new Assistant Professors joined our Faculty: Gabriel Kotliar, Janos Polonyi, Steven Stahler, and John Tonry. Two Senior Research Scientists were appointed to the Department: Richard Temkin and Yaacov Shapira. Five faculty members retired: Harald Enge, Robert Hulsizer, Benjamin Lax, Philip Morrison, and Clifford Shull. One senior research scientist, Charles Sargent, retired.

Faculty on leaves or sabbaticals during the year included Professors Alan Barrett, Ulrich Becker, Nihat Berker, Min Chen, George Clark, Henry Kendall, Walter Lewin, Scott Tremaine, Stanislaw Olbert, and James Young.

Faculty Sloan Fellows included Professors Charles Alcock, Farhi, Kotliar, Tremaine, and Tonry. Professor Herman Feshbach was co-recipient of the National Medal of Science. Other awards and honors received by Physics Faculty were the following: Professor Mildred Dresselhaus received the James R. Killian, Jr. Faculty Achievement Award; Professor Martin Deutsch received the Rumford Premium (American Academy of Arts and Sciences); Professor Toyochi Tanaka received the Nishina Memorial Prize [Nishina Foundation, (highest award given by The Physical Society of Japan)]; Professor Daniel Kleppner was named Lester Wolfe Professor of Physics and also received the Davisson-Germer Prize (The American Physical Society); Professor Bernard Burke was elected President of The American Astronomical Society; Professor Robert Birgeneau received the Wilbur Lucius Cross Medal from Yale University; Professor Bruno Coppi was honored with the Gold Medal of the University of Pavia; Professor Barrett and Senior Research Scientist William Donnelly received Alexander von Humboldt US Senior Scientist Awards; Professor Thomas Dupree received the 1985 Course VIII Graduate Student Council Department Teaching Award; Professor Harald Enge received a Doctor Honoris Causa from the University of Bergen; Professor Emeritus Robley Evans received the William D. Coolidge Award (American Association of Physics in Medicine); Professor Farhi was chosen MIT Class of 1956 Career Development Professor of Physics; Professor Robert Ledoux was named Cecil and Ida Green Career Development Professor of Physics; Professor Emeritus Jerrold Zacharias received the I.I. Rabi Award (Annual Frequency Control Symposium).

With regard to student awards, 25 students were inducted this year into Sigma Pi Sigma, the physics honor society associated with the National Society of Physics Students, operated under the auspices of the American Institute of Physics. Also, nine students were elected to Phi Beta Kappa: Edward Ajhar, Tomas Arias, Matthew Austern, Sharon Klotz, Eric Raiten, Katherine Schwarz, Mohamd Shahriar, Ian Shand-Kovach, Alan Yamamura. The Orloff Prize for Physics, an annual prize given by the parents of Joel M. Orloff, Class of 1978, in his memory, was awarded to Michael Berger. Anjali Sastry was co-recipient of the 1986 AMITA Senior Award (Association of MIT Alumnae).

### CURRENT RESEARCH

#### Astrophysics Division

Research in the Astrophysics Division is concerned with problems that span the universe from solar system phenomena to the most distant observable objects. Observations are made with both ground-based and space-based observatories. A major portion of the current

effort is devoted to the development of new instruments. Theoretical research is carried out on a variety of topics including space plasma physics, stellar structure and evolution, and cosmology.

1. High Energy Astrophysics. Three major instrument development projects for future X-ray satellite observatories are presently in their design definition phases. MIT is one of three institutions that has been selected for participation in the X-ray Timing Explorer Project (XTE). The MIT Group is responsible for development of the all-sky survey instrument and for the data system. The XTE will be used primarily in the study of the variability of compact galactic X-ray sources. The Group is also developing the Bragg Crystal Spectrometer which is one of the four focal plane instruments selected for the Advanced X-Ray Astrophysics Facility (AXAF). Primary responsibility for development of the imaging spectrometer, also selected for the AXAF, has been assigned to MIT.

The systematic search for the optical counterparts of X-ray sources detected in the all-sky survey carried out during 1977-1979 with the orbiting High Energy Astrophysical Observatory (HEAO-1) continues to yield about 20 new identifications per year. The identified sources include active galactic nuclei, cataclysmic variables, Be stars, and other interesting and comparatively rare objects that can now be studied in greater detail with the analytical methods of optical and radio astronomy. The search is being conducted with telescopes in both the Northern and Southern Hemispheres and includes extensive collaboration with the Australian National University.

Data from the Einstein X-Ray Observatory (HEAO-2) have been used to study hot gas in elliptical galaxies in a continuing program. An analysis of the radial distributions of the gas has been used to estimate the amount of gravitational matter contained in such galaxies. The data indicate the galaxies contain significant amounts of "dark" matter, i.e., gravitating mass that does not emit any detectable radiation. Furthermore, in typical cases the X-ray emitting gas is cooling at a sufficient rate as it flows in toward the center to provide the raw material for continuous formation of new stars at rates of 10 to 100 solar masses per year.

Studies have continued of the complex phenomena of quasi-periodic oscillations and X-ray bursts from accreting neutron stars in low-mass close binaries in collaborative studies using data obtained with the European X-Ray Observatory (EXOSAT).

Initial operation of the first set of instruments for the "Explosive Transient Camera" (ETC) commenced at an MIT site at the Kitt Peak National Observatory in Arizona. In addition, simultaneous observations of potential sites of gamma ray bursters were also carried out with the ETC and the European EXOSAT X-Ray Observatory. The ETC is designed to detect brief outbursts of light from celestial objects. Such outbursts, lasting for a few minutes or possibly much less, are known to be emitted by some of the sources of gamma-ray bursts that have been detected in satellite experiments. The primary purpose of the facility is to locate and identify these sources while, at the same time, opening a wide new range of astronomical parameter space to exploration.

2. Radio Astronomy. The investigation of the fine radio structure and the search for the optical counterparts of selected radio sources discovered in the deep survey has continued, with special attention devoted to candidates for identification as gravitationally lensed quasars. During an observing run at the Kitt Peak 4-meter Mayall telescope, planned as a part of this on-going project, a remarkable discovery was made by a joint Princeton-MIT team of two apparently identical quasar images separated by two arc minutes. This separation is much greater than that of any established gravitationally lensed pair of quasar images, and if truly a double image caused by gravitational lensing, implies the presence in space between us and the quasar of an entirely new kind of object, perhaps a black hole of  $10^{15}$  solar masses or a "cosmic string" which some theorists have suggested may be a remnant of the Big Bang.

3. Optical Astronomy. Observations of the neighboring galaxy M32 have shown that its stars have a dramatic, centrally-peaked rotation pattern. The rotation velocity is so great that it can only be explained by the presence of a massive dark object at the center of the galaxy. A project has also been undertaken to synthesize models of elliptical galaxy dynamics which are consistent both with optical observations of surface brightness and velocity dispersions and with X-ray observations of hot coronae. The goal is to provide better constraints on the extent of massive dark halos and on the anisotropies of stellar motions.

Cooling flows in elliptical galaxies and the properties of galaxies with X-ray active nuclei are continuing topics of optical investigation in projects which have been stimulated by the X-ray research and which are being carried out at the McGraw-Hill and other observatories.

Also concerned with the properties of elliptical galaxies are studies of faint morphological disturbances caused by interactions between galaxies.

4. Gravitational Radiation. The 1.5-meter prototype interferometric gravitational wave antenna has been used in a sensitive search for impulsive and periodic signals, with negative results to date. While testing and observation continues on the 1.5-meter device, work has begun on a 5-meter prototype to be installed in the newly-renovated high bay space of MIT Building 20.

The Caltech/MIT Laser Interferometric Gravitational Wave Observatory Project has also made substantial progress in the past year. Land acquisition has begun at the Maine site for a 4 km antenna; plans have been completed for the pre-development studies, and requirements for the large antennas have been drawn up in preparation for a detailed engineering design of the system.

5. Cosmology. Testing and characterization of the instruments for the Cosmic Background Explorer Mission have been underway for the past year. In addition to a long association with the Far Infrared Absolute Spectrometer instrument, the Group has recently become more deeply involved with the Diffuse Infrared Background Experiment which is an absolute photometer designed to measure the diffuse background between 1 and 300 microns in 16 bands. Satellite construction and testing are proceeding according to schedules.

The flight dewar for the balloon-borne cosmic background anisotropy experiment is being tested. Construction of the flight electronics is also underway. The first flight is expected in early 1987. This experiment intends to search for anisotropies in the background radiation of a few parts in  $10^5$  using four spectral bands between 1 and 25  $\text{cm}^{-1}$ . Two of the four bands will be used to monitor dust emission which is an expected contaminant for the cosmic background signal.

Some of the deepest problems of the early universe and the evolution of structure involve the phenomena of chaos and the transitions from ordered to chaotic systems that are encountered in nonlinear dynamics. Research in nonlinear dynamics has focused on experimental studies of transitions to chaos in nonlinear electronic systems, in particular on transitions from quasiperiodicity to chaos which are not as well understood as other transitions. Several circuits have been built which exhibit these transitions, and apparatus has been assembled to collect and analyze data generated by these circuits. Numerical and theoretical computations indicate that the transitions conform partially to current theoretical ideas but also indicate that these theories, in part, are inadequate. The current research will be continued and extended to higher dimensional systems.

6. Theoretical Astrophysics. Areas of current theoretical research include the nature of planetary rings, star formation and the earliest stages of stellar evolution, the properties of collapsed objects such as degenerate dwarfs and neutron stars, the effects of shock waves in interstellar and intergalactic media, and the origin and structure of galaxies.

Theoretical studies have been made of the nature and origin of binary systems containing collapsed objects and/or very low-mass stars. Detailed calculations have been used to interpret the observations of the first known "brown dwarf", which was recently discovered in a nearby binary stellar system. Fully hydrodynamic computations of the reprocessing of a gamma-ray burst from a neutron star in the atmosphere of a very low-mass companion star have been carried out, in an effort to model the optical flashes that have been observed from several gamma-ray burst sources. A new test of the theory of advanced stages of stellar evolution, which relies on the observational properties of binary stellar systems containing degenerate dwarfs, is currently being developed.

Another set of topics presently under investigation lies on the borderline between astrophysics and high-energy physics. The possibility that the "dark" matter in the universe might be composed of the "shadow matter" predicted by certain particle theories, including one version of the very attractive superstring models, is now under examination. The properties of localized regions of cosmic inflation have been investigated; it has been found that such a region can grow without limit by creating its own space, without expanding into the noninflating region.

7. Space Plasma Physics. Voyager 2 successfully encountered the planet Uranus in January 1986. Data from the Plasma Science Experiment on Voyager obtained during the encounter are being processed by the Space Plasma Physics Group to provide the first characterization of the plasma within the magnetosphere of Uranus, including sources and sinks, composition, and dynamics. Uranus provides the only example of an oblique magnetic rotator in the solar system. The observed magnetospheric plasma is primarily comprised of protons and electrons

and is more akin to laboratory plasmas than are those in the magnetospheres of the other planets. As an unexpected byproduct of the encounter, a general theory has been developed of plasmasphere formation, which relates convective transport time to the angle between the solar wind flow and the planetary spin axis. This theory not only explains one of the key observations at Uranus, but also provides insight into plasma transport in the magnetospheres of the other planets. Voyager 2 is also providing information on solar wind conditions during its cruise from Uranus to Neptune. Consistent with the observations of the Pioneer 10 and 11 spacecraft, there is still no evidence in the Voyager plasma data of the heliopause, the boundary between the region of space dominated by the solar wind and magnetic field and true interstellar space. Voyager 2 remains healthy. Planning for the Neptune/Triton encounter in August 1989 continues on schedule.

Analysis of plasma data obtained during the Voyager encounters with planets Jupiter and Saturn continues. The results are providing detailed information on plasma flow and thermal anisotropies in the complex magnetospheres of these planets. A preliminary investigation of disturbances in the Magnetosphere of Jupiter, which were originally attributed to the Galilean satellite Ganymede, has been concluded. It has been found that a more likely explanation of the disturbances is a plasma instability, similar to that which limits confinement in tokamaks, which is triggered by changes in the ram pressure of the solar wind upstream of Jupiter.

The highly successful fly-by of Halley's Comet by the Giotto spacecraft in March 1986 provided a rich yield of data concerning the composition of cometary material and its interaction with the solar wind. Data from the mass spectrometer experiment have shown that the solar wind flow picks up photoionized  $H^+$  that left the nucleus of the Comet as neutral hydrogen. These ions appear in the velocity distribution functions as an approximately complete spherical shell surrounding the distribution functions of the solar wind itself. The experiment detected a distinct bow shock around the Comet, in sharp distinction to the lack of such a shock in the observations of the International Cometary Explorer spacecraft at the Comet Giacobini-Zinner. The mass spectra measure by Giotto show a striking richness of  $C^+$  ions. These ions cannot be associated with the photodissociation of  $CO$ ,  $CH_4$  or  $CO_2$ ; the current hypothesis is that the carbon is in the dust grains themselves or is released from the surface of the cometary nucleus.

#### Atomic, Condensed Matter, and Plasma Physics Division

1. Atomic, Molecular, and Laser Physics. Maser action has been obtained in spin-polarized atomic hydrogen, pointing the way toward a device whose stability may one day far exceed the best of today's atomic clocks. Spin-polarized atomic hydrogen gas is a quantum fluid that has been under study for some time at MIT; it remains in the gas phase down to the absolute zero of temperature. The hydrogen maser is the most precise clock available and is used widely for a variety of scientific measurements. Such a maser operating at cryogenic temperatures has the potential for unprecedented stability, possibly a factor of a thousand better than that of existing clocks. The cryogenic hydrogen maser demonstrated at MIT was a natural outgrowth of basic research aimed at magnetically cooling spin-polarized hydrogen to record low temperature.

In the past it was believed that an excited atom would always radiate to the ground state by the process called spontaneous emission. In principle, however, by putting an atom in a cavity its spontaneous emission can be "turned off", creating a fundamentally new type of atomic state: A stable excited state. This idea has now been experimentally realized; initial measurements indicate that the lifetime can be at least 10 times as long as in free space.

Efforts are underway to trap a single charged atom in a magnetic field. This will make possible ultrasensitive mass measurements using cyclotron resonance.

New aspects of quantum transport phenomena in atomic and molecular vapors have been investigated using laser photon echo techniques. Experiments have studied quantum superposition state scattering, for which there is no classical analog. Results include measurements of (a) two-level optical radiator collision-induced velocity changes with a few cm/s resolution; (b) magnetic state scattering for isolated multipole moments; (c) resolution of velocity changes accompanying collision-induced molecular radiator reorientation.

Two-level optical superfluorescence (SF) studies have demonstrated that coherent ringing is an intrinsic property of SF in extended samples, resolving a long standing controversy. New measurements of SF in a cavity currently are in progress to study quantum fluctuations



in a single longitudinal and transverse mode of the optical field in a cavity, and the SF quantum initiation process.

Biomedical studies are in progress to develop a new type of catheter for "laser angioplasty", the removal of atherosclerotic plaque by means of laser light delivered via optical fibers. A theory has been developed to model thermal laser ablation; the results agree with dosimetric experiments in human cadaver arteries. In addition, a spectroscopic method for distinguishing normal artery from plaque based on laser-induced fluorescence has been developed. This will make possible in vivo imaging of coronary artery disease.

Laser-induced nuclear orientation has been successfully applied in a table top experiment to measure the laser-induced anisotropy in the gamma ray decay distribution of short-lived ( $^{85}\text{mRb}$ ) atoms. Values for the nuclear magnetic moment and isomer shift have been obtained. The lifetime of this nucleus is a thousand times shorter than that of any previously studied by optical methods. Present experiments to obtain sub-Doppler narrow gamma resonances are in progress.

2. Condensed Matter Physics. The prediction by MIT theorists of universal conductance fluctuations has been confirmed in a wide range of experiments around the world. The prediction is that at very low temperatures all metals and doped semiconductors will display fluctuations of their conductance from one sample to another, one magnetic field to another, or one value of the Fermi energy to another and that these fluctuations will have a magnitude of order  $e^2/h$ . This universality has been verified for wires made of Au, Au-Pd, and Bi for silicon field-effect transistors. Experiments done through a collaboration between the Physics and Electrical Engineering and Computer Science Departments first revealed the universal fluctuations in silicon devices. There is great excitement about the more recent prediction by the MIT theorists that these same fluctuations may be the origin of universal  $1/f$  noise.

The MIT/IBM beam lines at the National Synchrotron Light Source have now been fully commissioned. Both beam lines provide monochromatic highly collimated X-rays focussed at the sample position to a spot size under  $1\text{ mm}^2$  in area. One beam line utilizes perfect Si crystals as monochromator and analyzer, providing very high momentum resolution ( $10^{-4}\text{ a.u.}$ ) while the other employs Ti-Si multilayers and a position-sensitive detector. The latter provides the most intense monochromatic (one percent) laboratory X-ray beam in the world. The first experiment performed on the high resolution spectrometer was a study of the growth of the hexatic phase in a liquid crystal material labelled 80SI. The term "hexatic" symbolizes a state of matter intermediate between normal liquids and solids. In a hexatic phase the system has short range positional order as in a liquid or glass but long range orientational order as in a crystalline solid. The MIT Group has succeeded in growing a single crystal hexatic in 80SI and in studying quantitatively the development of the crystalline axes as a function of temperature. The simultaneous development of the positional order was also studied. The transition is continuous and reversible so that one can study the evolution of the order either on freezing or on melting. These experiments, in turn, have led to the construction of a new, highly successful theory for the growth of hexatic phases in three dimensions.

Theoretical work in statistical mechanics has concentrated, within the last year, on magnetic systems under random fields. A general renormalization-group theory was produced for the internal energies near a second-order phase boundary under random fields. A modified hyperscaling relation for the critical exponents was obtained.

A renormalization-group calculation was carried out, for the first time, for the random-field, random-bond three dimensional Ising model. The renormalization-group recursion of the full coupled probability distributions of the local fields and energies was used. Phase diagrams, specific heats, and magnetizations were evaluated.

Microscopic studies of liquid crystals and surface systems have also continued, respectively yielding reentrant smectic-nematic transition enthalpies and selenium-on-nickel phase transitions.

It has become possible to calculate the total energies of solids with sufficient accuracy to predict structures. These techniques have been applied to the prediction of the stability of defects in amorphous and crystalline semiconductors; of the structure of silicon, germanium, and GaAs surfaces; and to the migration of defects in silicon. The most novel use of this approach has been to calculate coupling constants between spins on surfaces which are then used as input to predict the thermodynamic properties of the magnetic system.

A program to study semiconductors containing large concentrations of ions with large spin, semimagnetic semiconductors, has been very successful. Laser-excited photoluminescence experiments at various magnetic fields suggest the formation of magnetic polarons: A state of an electron, bound to an impurity, whose energy is lowered by exchange coupling to the spins of the magnetic ions. Studies of the magnetic susceptibility show that the ions are randomly distributed which is important for theoretical modeling.

3. Plasma Physics. Radio frequency (RF) current drive (use of phased electromagnetic waves to drive toroidal current) was demonstrated in the Versator II and Alcator C tokamaks. There were concomitant studies of influence of RF current drive on plasma stability and transport properties. Significant progress has been made in the past year in several experiments which have taken advantage of the newly upgraded capabilities of Versator II, including the ability to run fully RF driven plasmas without ohmic heating. With a new 100 kW RF system operating at 2.45 GHz, fully RF driven plasmas have been achieved at densities as high as  $\bar{n} = 10^{13} \text{cm}^{-3}$ , substantially exceeding the 800 MHz density limit; and current drive effects are observed up to  $\bar{n} = 2.5 \times 10^{13} \text{cm}^{-3}$ . The possibility that nonlinear parametric decay instabilities prevent the wave power from reaching the center of the plasma above the density limit is being investigated.

The propagation and absorption of lower hybrid waves in toroidal plasmas has been the subject of several experiments on Versator II. A microwave scattering diagnostic has been used to detect the externally launched 800 MHz lower hybrid waves in the current drive regime.

Ongoing experiments are investigating the possible changes in the energy confinement time in partially and/or fully RF driven plasmas. Further experiments attempting to identify the physical mechanism responsible for the improved confinement behavior are underway using magnetic probes in Versator II.

In 1985 construction of a new electron-cyclotron resonance (ECRH) system began. The ECRH experiment employs a gyrotron power source which has been constructed at the Naval Research Laboratory. The gyrotron will operate at a frequency of 35 GHz at a power level of 150 kW. The design of the transmission system and antenna are being carried out at MIT. The aim of these experiments is to test heating and current drive processes using combined RF power near the lower hybrid frequency and the electron-cyclotron frequency. Also under construction is a new current drive experiment which will employ the fast lower hybrid wave at 800 MHz, which will be injected in conjunction with 2.45 GHz slow waves. The goal of these experiments is to improve the overall current drive efficiency.

In the Alcator C Experimental Program the following major experiments were pursued in the past year:

- a. Energy Confinement Studies in fully and/or partially lower hybrid driven plasmas.
- b. "Sawtooth" Suppression Experiments in the presence of RF current drive in mostly OH driven plasmas, with the goal of improving the central energy confinement time. The goal of these experiments is to improve the energy confinement time in conventional tokamak regimes, as well as find means to achieve steady state tokamak operation.
- c. Ion Cyclotron Range of Frequencies (ICRF) Heating Experiments at High Densities. These experiments include the novel concept of ion Bernstein wave heating (IBW) (where significant increases in the ion temperature were observed) as well as the more conventional fast wave heating. The IBW heating scenario resulted in significant improvements of the particle, and possibly energy confinement times even under conditions of edge absorption. Novel CO<sub>2</sub> laser scattering techniques were employed to determine the radial penetration of IBW into the tokamak plasma. The goal of these experiments is to find optimal ways of heating tokamak plasmas at ultrahigh densities ( $\bar{n}_e < 1 \times 10^{20} \text{m}^{-3}$ ) in devices such as the planned "Alcator C-Mod" and the "Compact Ignition Tokamak".
- d. Pellet Injection Experiments, with the goal of maximizing the "confinement product"  $n\tau_E$ , as well as studying the physics of plasma fueling at reactor relevant densities.

In January of this year a new Division of Coherent Electromagnetic Wave Generation was established in the Plasma Fusion Center. The primary objective of this Division is to develop a basic experimental and theoretical understanding of coherent radiation generation by free electrons for wavelengths in the 1  $\mu\text{m}$  to 1 cm range. Particular emphasis is placed on the development of free electron lasers, gyrotrons and novel radiation sources. A second area of research relates to theoretical studies of the basic equilibrium and stability properties of non-neutral electron flow in high-voltage diodes. A third area of

research involves basic theoretical and experimental investigations of laser-pumped, far infrared molecular gas lasers, including studies of laser tuning and efficiency.

In the areas of free electron lasers, studies are underway concerning the efficiency enhancement by means of tapering the wiggler period and/or amplitude. In addition, there are studies of various innovative wiggler configurations.

During the year a new experimental concept, Ignitor, developed at MIT and overseas, became the major national objective of the research program on controlled nuclear fusion. This consists of a compact, high magnetic field experiment, incorporating new technological solutions, that can prove whether a plasma composed of heavy hydrogen isotopes, can reach fusion ignition conditions. This in fact can be considered the proof of scientific feasibility of the fusion reactor. The relevant experiment has been envisioned as the first step of a large-scale international cooperative effort that has been spurred by the agreement reached on this subject at the Geneva summit meeting between Gorbachev and Reagan.

Another development that has become popular is a theoretical idea: That of the "Principle of Profile Consistency" that was proposed at MIT several years ago. According to this principle, the temperature profile was predicted to remain insensitive to changes in the source of plasma heating while, if the known "classical" transport theories were valid, the temperature profiles would have changed. An extensive series of experiments carried out in the major laboratories of the world have confirmed the validity of this principle.

### Nuclear and Particle Physics Division

1. Experimental Heavy-Ion Physics. Nuclei are normally kept apart by strong Coulomb forces. When nuclei collide with sufficient energy to overcome that barrier, a richness of phenomena is observed whose study has given us deep insights into nuclear properties. For almost two decades the Heavy-Ion Group at MIT has carried out these studies in order to investigate the properties of nuclei at the limits of their stability.

The imminent ability of accelerators to produce heavy nuclei with energies a thousand-fold in excess of the Coulomb barrier holds the promise of studying nuclei at the limits of their density and energy. The interaction of extreme relativistic ions with targets as heavy as uranium is expected to produce matter densities and energy densities almost an order of magnitude greater than normal. New phases of nuclear matter may appear. It has been conjectured that in these dense states a plasma may be formed from the quarks which make up the nucleons in the nuclei and the gluons which bind the quarks. The interactions at close quarters may break the bonds which confine the quarks and thus set them free. It is to these studies that the Heavy-Ion Group has now turned its attentions.

The studies of these phenomena will begin with beams of 500 GeV sulphur nuclei produced at Brookhaven National Laboratory (BNL). Neither the energy nor the mass of these initial beams is expected to be high enough to produce a quark-gluon plasma, but the densities will still be an order of magnitude greater than any hitherto observed under controlled conditions. The objective in the coming years is to eventually reach collision conditions that approximate those conjectured to have occurred in the early stages of the expanding universe.

2. Intermediate Energy Physics. The principal activity in this field is centered at the BLA, which is operated under the joint auspices of LNS and the Department of Energy (DOE). The Laboratory serves the national community, providing intermediate energy electron and photon beams for precision studies of nuclear structure and for reaction studies aiming at fundamental understanding of the nuclear force. The intermediate energy research programs of MIT faculty and research staff, both at BLA and at off-campus facilities, are described below.

Twenty-six MIT graduate students were associated with the intermediate energy research program during the past year. One student, William Burger, was awarded the Rosen Prize, given annually for thesis research carried out at the Los Alamos Meson Physics Facility. A recent graduate, Charles Hyde-Wright, was awarded the Demos Prize, given annually for outstanding doctoral research carried out at the BLA.

A large fraction of the faculty and senior research staff participating in intermediate energy nuclear physics at BLA performed a difficult set of experiments on the tritium nucleus during the past year. The aim of the program is an extensive and precise characterization of the electromagnetic structure of three-body nuclei. This system is rather special in permitting a particularly sharp confrontation with theoretical expectations while still possessing a structure rich enough so as to bear upon a host of important issues. The technical challenge arose principally from the need to contain a large

inventory of radioactive tritium in a geometry appropriate for precision experiments. Analysis of the data will be completed over the next year. Preliminary analysis of elastic data has already provided an important test of meson contributions to the structure of tritium and helium-3. The role of three-body forces and of modified nucleon structure in the nuclear medium will be addressed in the more complete analysis. The inelastic data and the precision of the elastic data are unique to the BLA experiment.

Precision electron scattering studies of the structure of more complex nuclei have continued. For example, the magnetization distribution in oxygen-17 has been resolved to an unprecedented short distance scale.

A major effort has been and will continue to be focused on studying nuclear response to large energy transfer. A benchmark coincidence study of protons knocked out of the nucleus by electrons is underway. The goals of the program include understanding single-nucleon motion in the nucleus, modifications of nucleon structure in the medium, and contributions to the electromagnetic current arising from the close interaction of two (or more) nucleons. The first results of the measurement program are extremely provocative. For example, a surprisingly large fraction of the nuclear response appears to involve the direct ejection of more than one proton. Further, even qualitative features of the nucleon electromagnetic coupling, such as the ratio of coupling strengths to photons of different polarizations and the variation of coupling strength with momentum transfer, appear to be modified in the nuclear environment. These results are widely held to be associated with nucleon substructure, but a far more extensive experimental characterization is needed for guiding quantitative theoretical approaches.

Direct emission of single protons by intermediate energy photons has been studied. An interesting scaling phenomenon has been found in comparing data for different energies and may provide the clue needed for extracting information about the probability for finding nucleons with very large momentum in the nucleus. This in turn would be very instructive for understanding the short-distance structure of the nucleus. A large effort is underway to clarify this by examining the same process for neutron emission. This is a difficult task, but the first data should be available in the coming year.

A unique test of the unified theory of electromagnetic and weak interactions, to be carried out at BLA, is in preparation. The experiment aims to measure the very small asymmetry expected ( $\sim 10^{-6}$ ) in elastic scattering and right- and left-handed electrons from nuclei. A major obstacle for such an experiment is the need to produce a beam of polarized electrons; this has recently been accomplished after a long development program.

Another major experiment in preparation, again involving many of the faculty and senior research staff, aims to measure the monopole and quadrupole charge distributions of the deuteron for the first time. It is perhaps surprising that these fundamental quantities are not individually yet known but, with the completion of ongoing upgrades the Bates accelerator will be the first with the required combination of energy, intensity, and duty factor to permit the measurement to be made in an interesting regime. There are many theoretical speculations about the short-distance structure of these charge distributions; and the data, which are expected to be taken by the end of 1987, are awaited eagerly.

Complementary to the Bates experiments are investigations by the MIT group at other accelerator facilities. The largest program is that examining selected pion-induced reactions at the Los Alamos Meson Physics Facility. This program aims at isolating pion interactions with nucleons and with nucleon clusters in the nuclear medium, particularly in the energy regime corresponding to the lowest excitation of the nucleon. In doing so, one expects to learn how internal nucleon structure affects the strong interaction of baryons. Both pion annihilation and charge-exchange reactions are being examined. The former have proved rather convincing in revealing many-body effects in the annihilation process, a process intimately connected with the origin of the nuclear force. Single and double charge exchange studies are used to isolate the pion interaction with nucleon pairs. Such a unified approach encompassing scattering from and absorption on nucleon clusters is essential for advancing our understanding of strong interaction dynamics.

Another group is collaborating with BNL physicists in a study of hypernuclei. These are nuclei in which one of the nucleons is replaced by a particle carrying strangeness (i.e., one of the light quarks which make up ordinary matter is replaced by a strange quark). Both  $\Lambda$ - and  $\Sigma$ - hypernuclei have been studied, leading to an experimental determination of the interaction strength of strange particles with nuclear matter. Electromagnetic transitions in  $\Lambda$ -hypernuclei are being studied, particularly with a view towards a reliable measurement of the  $\Lambda$  spin-orbit force. In addition, the group continues to investigate new methods for the detection of solar neutrinos.

### 3. Experimental Particle Physics.

a. Accelerator Physics Collaboration (APC) Group. The APC Group is conducting experimental research at Fermi National Accelerator Laboratory (FNAL) in Illinois and the Gran Sasso Laboratory (GSL) at L'Aquila, Italy.

The Group has recently taken data at FNAL in the world's highest energy neutrino beam, utilizing a holographic bubble chamber. This experiment is investigating a new domain in neutrino physics where new phenomena might be found. The experiment in GSL, which is the world's largest underground laboratory, will study particle physics problems and astrophysics problems. The particle physics problems are related to the possibility of a new type of particle being emitted from Cygnus X-3. These studies could confirm emission of such particles and provide information on the mechanisms involved and the properties of the source. This experiment can make the best search for neutrino oscillation. The Group will also study the production of solar neutrinos and will measure the yearly rate of collapsing stars in the universe. Another objective is the search for point sources in the universe emitting high energy neutrinos.

b. Counter Spark Chamber (CSC) Group. The CSC Group is involved in a Fermi-based program of studying the structure of the nucleon and the structure of the weak interaction using neutrinos as a probe. The major focus has been on the analysis of the data obtained to determine the structure functions of the nucleon, as sensed by the weak neutral current, and to make detailed comparisons of the neutral and charged current interactions with the nucleon. The results obtained are consistent with the predictions based on the Weinberg-Salam-Glashow (W-S-G) weak electromagnetic unification theory and the quark-parton model and have yielded a new precision value of the weak mixing angle. The Group has continued its neutrino studies with Tevatron II, the Fermilab 1000 GeV accelerator. The major objective of the first experiment in this program has been the study of the "like sign" dimuon process, which presently is not understood.

In addition, the Group has recently entered into two other major collaborative programs. (1) The use of  $\mu$  mesons at the Tevatron to study nucleon structure and the mechanisms of particle production. The Group is participating in the construction of a spectrometer to be used in these studies. (2) The use of 50 GeV  $e^+e^-$  colliding linac beams (Stanford Linear Collider) at Stanford Linear Accelerator Center (SLAC) to investigate the physics of the intermediate vector boson  $Z^0$ . The collaboration is now collaborating in the construction of an advanced detector called SLAC Large Detector (SLD), which would exploit the new energy region to investigate a number of physics issues. In particular, they will search for Higgs particles produced in the decay of  $Z^0$ , and for processes involving heavy quarks with hitherto undiscovered flavors, in addition to investigating the decay channels of  $Z^0$ .

c. Lepton Quark Studies (LQS) Group. The LQS Group is also collaborating on the construction of the SLD detector. They are engaged in the development and construction of the Central Drift Chamber for the SLD detector.

d. Electromagnetic Interactions (EMI) Group. The EMI Group is engaged in two efforts in experimental high energy physics: One at the highest existing electron-positron colliding beam accelerator, PETRA, in Hamburg, Germany, and the other at the newly approved 240 GeV electron-positron accelerator, LEP, in Geneva, to be operating in 1990.

The work at LEP: The Group is leading a large construction effort, which involves 350 Ph.D. physicists from 12 nations, to build a large, accurate detector to measure photons, electrons, and muons precisely. The experiment is the first large-scale collaboration between physicists from the Soviet Union, The People's Republic of China, and the United States. The construction of this experiment is proceeding according to schedule and will be ready for data-taking by the time of the first LEP beam scheduled for the end of 1988. The purpose of this experiment is to understand the origin of the masses of elementary particles.

The work at PETRA: After its discovery of gluons, this Group has concentrated on the study of the properties of gluons to increasingly high orders of accuracy. Of particular importance is the Group's recent work on the determination of the second order coupling constant between gluons and quarks, showing that the general theory of strong interactions between quarks and gluons is understood. In addition, they have shown that the expected sixth quark, known as the top quark, is much heavier than previously expected. Their measurement of direct muon production has yielded a much better understanding of the ways in which different quarks transform themselves into ordinary subatomic particles. The Group plans to continue to take data with a new high resolution vertex chamber to study the lifetimes of new heavy particles.

## Theoretical Division

1. Nuclear Theory. An area of fundamental interest is the role of underlying quark and gluon degrees of freedom in the nucleon, in nucleon-nucleon interactions, and in nuclear structure. Although it is believed that the structure and interaction of hadrons are governed by QCD, there is as yet no quantitative theory of even the most basic questions: How do we understand the properties of a nucleon in free space, how is a nucleon altered when it is embedded inside a nucleus, and why is low-energy nuclear physics so little affected by the internal structures of nucleons? These questions are being approached both from the perspective of lattice gauge theory, and in the context of non-relativistic quark models. Studies of nuclear matter have focused on the clustering of quarks into nucleons and the experimental signature of non-nucleonic degrees of freedom. Hadron-hadron interactions have been studied in both the non-relativistic quark model and in the MIT bag model. A major new initiative has been undertaken in investigating the collisions of relativistic heavy ions. This includes a study of the properties, evolution, and hadronization of the quark gluon plasma in order to understand particle multiplicities and provide experimental signatures of new physical phenomena.

Nuclear many-body theory provides the foundation for many facets of nuclear theory and has therefore been an area of continuing interest. The success of relativistic models of nucleon-nucleus scattering has motivated continued efforts in the study of relativistic many-body theory. Recent developments in functional, integral, and stochastic methods have proven fruitful in a variety of applications, ranging from problems in traditional nuclear structure to the study of relativistic nuclear models and field theory. Progress has continued in the theory of nuclear collective motion, utilizing both time-dependent perturbation theory and the Born-Oppenheimer approximation.

Electromagnetic interactions have been a long standing focus of theoretical interest in the Group, both by virtue of the unique precision of the probe and the commitment to the experimental program in electron scattering at the MIT BLA. A detailed study has been made of the additional nuclear structure which is revealed by studies with polarized electron beams, with polarized targets, and by coincidence experiments. The structure of the electromagnetic current operator in nuclei is being studied, both from the perspective of meson exchange currents and quark substructure.

2. Particle Theory. The "standard theories" of the interaction of quarks and leptons through gauge fields, QCD for the strong interactions, the W-S-G theory for the electromagnetic and weak interactions, and general relativity for gravitational interactions are powerful and in complete agreement with experiment. But they contain no answers to the fundamental question, why do we have this particular hierarchy of particles and interactions? Clues can be sought within the structure of quantum field theory itself, though precedent suggests that further experimental input will be needed to make real progress. The Group has continued to study a possible unorthodox dynamics of the standard theory, but must now wait for more experiments at higher energies. Much thought has been given to this next generation of experiments, in particular proton-antiproton collisions in the TeV range, to see how the most useful information could be obtained.

The most radical development has been the theory of superstrings, which endeavors to unite all physics at the Planck scale, where quantum effects in gravitation start to dominate. Since this scale is quite inaccessible to experiment, internal consistency constraints of gauge field theory are used to restrict viable theories. The Group has gone part of the way toward constructing a field theory which would make manifest the presumed deep underlying symmetries that characterize superstrings and would make it conceivable to do nonperturbative calculations. Their work on the structure of gauge field theories has been stimulated by the developments in string theory. The richness and range of application show no signs of diminishing.

The one place where accessible physics comes close to the Planck scale is in studies of the very early universe. Work has continued on the inflationary scenarios for the development of the universe from the big bang to the present state. Less drastic extrapolations of our particle physics knowledge have been applied to astrophysical problems such as the properties of hypothetical stars made of matter with a different quark composition from ordinary nuclear matter.

## EDUCATIONAL ACHIEVEMENTS

Finally, the Department has continued this past year to maintain a relatively stable number of graduate and undergraduate students, as well as a relatively constant number of credit units per faculty member. This year, the number of undergraduate majors was 223, and the number of graduate students was 302. The number of degrees awarded totaled 74 S.B., 9 S.M., and 49 Ph.D.

Faculty in the Department continue to receive substantial research funding, primarily from the Departments of Energy and Defense, the National Science Foundation, and the National Aeronautics and Space Administration. This has been particularly gratifying in view of the financial limitations that have been placed on these agencies with regard to funding basic research.

Course VIII-A this past year attracted approximately 25 students. Recently introduced into the departmental curriculum, Course VIII-A (Physics with Electrical Engineering) enables students to fulfill all requirements for the S.B. Degree in Electrical Engineering.

We continue to make use of resources within Project Athena by offering a freshman elective physics laboratory, in which computers are an integral part of experimentation, involving data acquisition, data fitting, and error analysis. In addition to the computer-oriented laboratory supported by Athena, we have prepared a freshman laboratory especially designed for students in the 8.012 and 8.022 sequence. Its special feature is that recitation instructors also serve as laboratory instructors for their recitation students.

JEROME I. FRIEDMAN

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## Bates Linear Accelerator

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The William H. Bates Linear Accelerator Center, located in Middleton, Massachusetts and operated under the joint auspices of MIT and the Department of Energy, serves as the national user facility for intermediate energy electro-nuclear physics. The Laboratory supplies high intensity (average current  $\sim 50 \mu\text{Amps}$ ), high quality electron and photon beams with energies in excess of 800 MeV. A spectrometer of unmatched resolution supports a program of precision measurements of nuclear electromagnetic charge, current and magnetization distributions. A second experimental area is equipped to support a vigorous program of photoreaction studies, with protons, neutrons, charged and neutral mesons, and photons detected with good resolution. Further, the electron beam duty factor of  $\sim 1\%$ , together with a unique set of magnetic spectrometers, permits an exploratory program of coincidence studies. This program has been particularly compelling in pointing towards a major facility upgrade needed for effectively pursuing new directions in the field; this upgrade will be described below. Beam time is assigned to experimental proposals on the basis of scientific merit with the advice of a Program Advisory Committee with international representation. Roughly one third of the beam time is presently assigned to MIT faculty and staff. There are currently 210 active participants in the research program, drawn from 65 universities and research laboratories; this is a substantial increase in numbers, reflecting the unique capabilities developed at Bates. The MIT-Bates intermediate energy research program has been exceptionally effective in graduate education, producing between 5 and 10% of the nation's Ph.D.'s in nuclear physics during the last several years.

Over the past year, the major effort at Bates has been an electron scattering study of the three-body nuclei, tritium and helium-3. The experiment was led by scientists from MIT and Virginia, with participants from six other universities deeply involved. The three-body nuclei are particularly important because they are simple enough to permit quantitative confrontation with theory and yet are rich enough to display many of the phenomena of greatest current interest. The major obstacle lies in containing a large inventory of radioactive tritium in a configuration suitable for precision experiments. The Bates experiment employed 140,000 curies of tritium in a high pressure gas cell. Elaborate safety precautions were followed at each step. The MIT Radiation Safety group was intimately involved in the preparation for and execution of the experiment and are to be commended highly; experienced scientists from LNS, Los Alamos, and the National Bureau of Standards formed a special oversight committee for examining the target design. The experiment was completed safely and successfully, with analysis of the data in progress. The data are expected to be important for a variety of issues, including the role of mesons and nucleon excitations in nuclear structure, the magnitude of three-body forces, and the modifications of nucleon substructure in the nuclear medium.

The research program in another experimental area centers on studies of nuclear response to large energy transfer, i.e., energies large enough to produce mesons and to produce internal excitation of the nucleon. For example, the first measurement of elastic photon scattering from a nucleus above the threshold for pion production was performed by a BU-MIT group and will soon be extended to higher energies. This program, together with charged pion photoproduction studies carried out at Bates, mainly by the RPI and MIT groups, will lead to a better understanding of the interactions of excited nucleons.

An important exploratory coincidence program, in which high energy protons knocked out of the nucleus are measured simultaneously with the scattered electron, is being pursued by scientists from MIT, William and Mary, Maryland, Argonne, California State and other institutions. Their first results are extremely provocative in showing large deviations from the electromagnetic coupling measured for free protons. The implications of these results, while not yet fully understood, may be very significant for our understanding the role of nucleon substructure in strong interaction dynamics. The much more extensive experimental study demanded by these results argues strongly for the proposed Bates upgrade to high duty factor operation.

An MIT-Glasgow-South Carolina collaboration has found an interesting scaling behavior in the ejection of single protons by intermediate energy photons. This result holds promise for shedding light on the probability for nucleons to have very large momentum inside the nucleus. This elusive quantity is of great interest because of its sensitivity to the short-distance structure of nuclei. An MIT-led group is now preparing to examine the analogous process for neutron ejection. These results will be crucial for interpreting the underlying mechanism.



A collaboration led by Yale, MIT and Syracuse continues to prepare an experiment aimed at providing a unique test of the unified theory of electromagnetic and weak interactions. A major milestone was achieved recently in accelerating a beam of polarized electrons. The experiment will measure the very small asymmetry expected ( $\sim 10^{-6}$ ) in the elastic scattering of electrons with spin aligned parallel or antiparallel to the beam direction. Following this experiment, we anticipate a major program of strong interaction studies with the polarized beam. This will be a unique program, essentially using spin observables for the first time in electronuclear physics.

The Laboratory is now preparing for a major experiment aimed at resolving for the first time the full electromagnetic structure of the deuteron. This will be a very difficult experiment and will command a significant fraction of the Laboratory's resources. Major responsibilities for the experiment rest with groups from Alberta, MIT, Syracuse and Saclay. We hope to carry out the experiment in 1987.

The Laboratory accommodates various activities outside the mainstream of basic nuclear physics research. For example, a recent experiment found the interference between synchrotron and Cerenkov radiation predicted from classical electrodynamics, and studies of transition radiation with a goal of improved angiography are under way.

Substantial progress was made in the last year on a variety of important Laboratory upgrades. The polarized beam was already mentioned. The maximum electron energy was raised from 750 MeV to 825 MeV; with the ongoing upgrade of the RF system, we hope to reach 1000 MeV next year. In the experimental area, a new spectrometer was made fully operational and a high flux photon source completed. These capabilities have made qualitatively new research opportunities available.

The Laboratory has continued to develop plans for a major upgrade. The essential new capabilities are continuous beams and the provision of polarized targets. The former are needed to advance the coincidence program which is proving so interesting even with our limited duty factor. The latter is needed for full exploitation of spin observables, thereby realizing the full power of the electromagnetic probe. We have submitted a proposal to the Department of Energy for construction of a Pulse Stretcher Ring - Internal Target Hall complex. This would provide both capabilities at a total cost of 22.1 million. The scientific merit of the proposal was recently evaluated, in competition with other proposals, by the Nuclear Science Advisory Committee. They assigned very high scientific priority to the proposed upgrade. Discussions about funding are being carried on with the Department of Energy.

ERNEST J. MONIZ

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## Cell Culture Center

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The Cell Culture Center at MIT was established in 1974 to serve as a facility and resource for all biologists throughout the United States. The principal source of funding for the Center is the National Institutes of Health (NIH). The Center is headed by Professor Phillips W. Robbins, Principal Investigator and Donald J. Giard, Director. The mission of the Center is to produce cells and cell products on a large scale in order to allow scientists to conduct novel and important experiments in basic cell biology that could not be accomplished with the materials and resources in the investigator's own laboratory. The Center is working directly with individual scientists on basic research problems and, in addition, is conducting an active program in the development of new techniques for large scale cell production.

### Production

During the period July 1, 1985 to June 30, 1986, the Cell Culture Center provided animal cells and their products to 46 research groups throughout the United States. Cells were produced in a variety of ways including roller bottles, suspension cultures, and microcarrier cultures. During this period, more than  $10^{13}$  cells were produced as the demand for cells continued to increase. Examples of projects completed during the past year include:

- 168 liters of conditioned medium from BRL-3A cells for Syracuse University, Syracuse, New York.
- 180 liters of rat basophilic leukemia cells for Harvard Medical School, Boston, Massachusetts.
- 600 roller bottles of RFP-EC cells for MIT, Cambridge, Massachusetts.
- 270 liters of lymphoblastoid cells for the Dana Farber Cancer Institute, Boston, Massachusetts.
- 200 roller bottles of SV-BHK cells for Oregon Health Science Center, Portland, Oregon.
- 200 liters of TA3 cells for Washington University, St. Louis, Missouri.
- 150 liters of MOLT-4 cells for the University of Michigan Medical Center, Ann Arbor, Michigan.

### Cell Sorter Laboratory

The Cell Sorter Laboratory was established in 1980 as a discrete element of the Cell Culture Center to serve as a local facility and resource for cell biologists primarily in the Northeastern United States. Its purpose is to provide analysis and separation of cells and other small biological particles for qualified researchers who do not have sufficient resources and equipment in their own laboratories for using this type of specialized technique.

The Cell Sorter Laboratory continues to provide a valuable service to researchers in the greater Boston area. A total of 34 laboratories utilized the cell sorter service during the past year.

### Research and Development

Research at the Center over the past year has focused on the following areas:

- 1) Development of Optimization Strategies for Mammalian Cell Processes. The emphasis on this project has been to develop the principles and strategies necessary for obtaining mathematical descriptions of metabolic kinetics in mammalian cell cultures. An example of this approach has been the use of differential equations coupling glutamine catabolism with ammonium production. By using these equations as the basis for the addition of glutamine to the medium, the production of ammonia, a toxic end-product of catabolism, was reduced by 60%.
- 2) Optimization of Large-Scale Cell Culture Reactors. Fundamental principles required to optimize the design of large-scale cell culture reactors are being examined. In particular, the effects of fluid motion and agitation are being determined and correlated with newly developed theories. Recent work has shown that animal cells, which are relatively large and fragile, can be damaged through direct exposure to turbulent eddies, bubbles, and particles collisions. These damaging hydrodynamic processes have been successfully described through quantitative models of fluid flow fields.
- 3) Dynamic Chromatography. Dynamic chromatography, which involves the adsorption of proteins from solution onto particles of adsorbent using a staged series of well-stirred batch contacters, has been used to enhance selectivity in purification due to differences in rates of uptake of different proteins. Specifically, controlled pore glass was used to preferentially recover human gamma interferon from spent medium obtained from recombinant Chinese hamster ovary cells.

DONALD J. GIARD

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## Center for Cancer Research

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The Center for Cancer Research has made steady progress during the past year. Research support for the Center has grown with the renewal of the NCI Cancer Center Support Grant for a period of five years and the development of a research grant from the Ajinomoto Company of Japan. The latter grant provides general support for the Center as well as specific support in the areas of cell biology and immunology. The Bristol-Myers Company continues to provide general support to the Center. The Center has two active searches for junior faculty appointments in the areas of immunology and the biochemistry of proteins regulating cell division. These appointments will bring the Center's total faculty to 13. Two changes in academic appointments have occurred during the past year. Professor Frank Solomon was promoted to full professor in the Department of Biology and Professor Thereza Imanishi-Kari left the Center to join the Department of Pathology at Tufts University School of Medicine.

The Center participated in several important advances in research. In the area of immunology, Professors Susumu Tonegawa and David Raulet have shown that a newly discovered gene family undergoes DNA rearrangements early in the development of T lymphocytes. These genes encode a protein similar in structure to the receptor proteins on the surface of T cells and may be involved in the restriction of specificity of the T cell. It is widely suspected that one of the functions of the T cells in the immune system is to destroy variant cells which might be progressing toward formation of a tumor. Elucidation of the factors controlling the specificity of T cells is of great importance. In the area of cell biology, Professor Richard Hynes' laboratory has made significant progress in defining the genetic structure of the gene encoding the protein fibronectin. This large protein binds to the surface of cells and provides part of a matrix for their growth and movement. The levels of fibronectin on the surface of cells decrease during transformation of normal cells to tumor cells and this may be related to their malignant behavior. Professor Hynes' laboratory has shown that the different forms of fibronectin are the results of alternative pathways for the splicing of the RNA from this gene. The various forms of fibronectin have distinguishable properties in that some bind more readily to cells. In addition, Professor Hynes' laboratory has also isolated a gene encoding the cell surface receptor for fibronectin and is now studying how the binding of fibronectin to the exterior of the cell is affected by signals within the cell and vice versa. In the area of virology and cell biology, Professor David Housman's laboratory has been able to isolate a cellular gene which, when amplified and perhaps mutated, renders the cell resistant to a variety of drugs used for chemotherapy of malignant tumors. The amplification of this and similar genes within tumor cells may explain the propensity of these cells to become resistant to certain classes of drugs.

The research and academic activities of the faculty of the Center have been recognized by a number of awards and prizes. Professor Susumu Tonegawa received the Bristol-Myers Award for his studies on genetic rearrangements in the immune system and he was also elected to the National Academy of Sciences. Professor Phillip Sharp received the Alfred P. Sloan, Jr. Prize from the General Motors Research Foundation for basic research in cancer in recognition of his studies on RNA splicing and gene expression. Professor Sharp was also named to the Class of '41 Chair at MIT. Professor Herman Eisen received an Outstanding Investigator Grant from the National Institutes of Health for the continuation of his important studies on the immune system. Both Professors Richard Hynes and Phillip Sharp were this year's Harvey Society Lecturers. As an indication of the teaching commitment of the faculty of the Center, Professor Frank Solomon again received the Graduate Teaching Award from MIT.

The Center had a number of faculty-rank visitors: Dr. Lowell Schnipper of Harvard Medical School, Drs. Judah Weinberger and Mark Pasternack of the same institution, and Dr. Jack Lawler of St. Elizabeth's Hospital. Two research fellows also trained in the Center this year, Dr. Jack Hensold from Beth Israel Hospital, and Dr. James Croop from the Dana-Farber Cancer Research Institute and Children's Hospital. The Center had 68 scientists training at the postdoctoral level, the majority of whom were supported by competitive fellowships, and 32 graduate students. Three students from the Center's laboratories obtained their Ph.D. degrees this year.

PHILLIP A. SHARP

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## Center for Space Research

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The Center for Space Research (CSR) conducts an active program of research in astronomy, space science and technology, with emphasis on experimental and theoretical investigations in support of various NASA missions. Although the primary source of support is from NASA, a substantial fraction of the research program is sponsored by the NSF and DOD. Specific areas of research include X-ray astronomy, planetary magnetospheric and interplanetary space plasma physics, the life sciences, properties of planetary surfaces and atmospheres, the detection of gravity waves, and optical and radio astronomy. A major part of this program concerns the analysis and interpretation of data from flight experiments carried out in these areas. The current long-range NASA flight program includes several missions in which MIT and the Center are heavily involved. Among these are Venus Magellan (MGN), Mars Observer (MO), Advanced X-ray Astrophysics Facility (AXAF), a large area X-ray Timing Experiment (XTE), Cosmic Background Explorer (COBE), and a large-scale investigation of the plasma environment of the earth as part of the International Solar Terrestrial Physics Program (ISTP). The Center also supports a program in theoretical astrophysics and a program of optical investigations carried out at the McGraw-Hill Observatory. An overview of CSR activities during the past year follows.

### RESEARCH IN X-RAY ASTRONOMY

#### Analysis of Data from Satellite X-ray Observatories

The archives of data obtained with MIT instrumentation on NASA satellites during the period 1975 to 1980 continue to furnish material for the investigation of high energy astrophysical phenomena. In addition, new data have been obtained from guest observations carried out on the European X-ray Observatory Satellite (EXOSAT), which recently ceased functioning after several years of productive life.

The Small Astronomy Satellite (SAS-3) archive has been used by Professor George Clark and his associates in the study of the atmospheric structures of the primary stars of eclipsing X-ray binaries. Professor Hale Bradt and Dr. Ronald Remillard have continued their investigations of the optical counterparts of X-ray sources originally located by the MIT experiment on the High Energy Astronomical Observatory (HEAO-1). Professor Claude Canizares and his associates have carried out a variety of X-ray spectroscopic investigations of X-ray sources with data from the Einstein Observatory (HEAO-2). Professor Walter Lewin has extended his studies of quasi-periodic X-ray oscillators (QPO's) which were discovered by him using the EXOSAT last year.

#### Advanced X-ray Astrophysics Facility (AXAF)

A team under Professor Canizares has continued the definition study of new instrumentation for the High Resolution Spectroscopy experiment planned for this orbiting facility. Work on the fabrication of sub-micron X-ray transmission gratings have continued in collaboration with Professor Henry I. Smith, Department of Electrical Engineering and Computer Science (EECS), and improvements have been made in the laboratory facilities necessary for testing Bragg crystal diffractors.

During the past year, work on the AXAF CCD Imaging Spectrometer (ACIS) entered the detailed design and definition phase. The scientific and instrumental activity for the ACIS program at CSR is being carried out under the direction of Dr. George Ricker, the lead Co-Investigator for the ACIS experiment (Dr. Gordon Garmire at Pennsylvania State University is the ACIS Principal Investigator). In addition, CSR has overall management responsibility for this experiment, which will culminate in a launch in mid 1994.

#### X-ray Timing Explorer (XTE)

XTE is a relatively inexpensive NASA X-ray Astronomy satellite program which has been proposed for launch in the early 1990's; experiments have been selected by NASA but full funding awaits final scheduling and approval of the mission. The main objective is to study the time-variability of celestial X-ray sources over time scales ranging from milliseconds to years. A CSR group under Professor Bradt is participating in mission studies and is beginning development of the scientific instrumentation for which MIT has a major responsibility. As part of this program, CSR is conducting laboratory studies of position-sensitive detectors for the Scanning Shadow Camera, which will serve as all-sky X-ray monitors.

#### McGraw-Hill Observatory

The McGraw-Hill Observatory, located on Kitt Peak near Tucson, Arizona, is run jointly by MIT, the University of Michigan, and Dartmouth College. For the past year, major activities have been the completion of the new 2.4m-diameter optical telescope, installation and testing of the primary mirror, adjustment and

alignment of the drive mechanisms, implementation of the new computer-driven control system, and assembly of the detector instruments. Most of the "growing pains" appear to have been overcome, and the telescope is being scheduled for astronomical use beginning in September. All indications are that this will be a first-class research instrument serving the entire astronomical community at MIT.

The existing 1.3m telescope continues to be heavily used by MIT astronomers, who carried out a wide variety of research projects ranging from comet Halley to the distant quasars. About half of the several dozen observing trips to Tucson were made by students, including some undergraduates. Data collected at McGraw-Hill Observatory by graduate students will form the basis of many thesis projects in planetary science and astrophysics.

Some highlights of work carried out at McGraw-Hill include the discovery by Drs. Jeffrey McClintock and Ronald Remillard of one of the best candidates for a black hole in a binary star system; searches by Dr. Ricker and Roland Vanderspek for optical counterparts to gamma ray bursters and to the mysterious "Perseus flasher"; studies of scattered light around comet Halley by Professor David Jewitt; examination of a bright, highly variable quasar-like object by Professor Bradt and Drs. Remillard and McClintock; measurements of the structures of planetary rings by Professor James Elliot and Dr. Edward Dunham; images of ripples of the light distributions of elliptical galaxies by Professor Clark; search for optical counterparts to X-ray sources by Professor Bradt, Drs. Thomas Markert, C. Megan Urry, and R. Remillard, and for counterparts to radio sources by Professor Bernard Burke; studies of cooling gas in galaxies and clusters of galaxies; and studies of the intrinsic colors of quasars by Professor Canizares and his students.

## RESEARCH IN SPACE PLASMA PHYSICS

### Interplanetary and Magnetospheric Plasmas

The Voyager-2 spacecraft successfully encountered the planet Uranus in January 1986. Data from the Plasma Science experiment (Professor Herbert Bridge, Principal Investigator) obtained during the encounter are being processed by the Space Plasma Physics group to provide the first description of the magnetosphere of that planet. Analysis of plasma data obtained during the earlier Voyager encounters with the planets Jupiter and Saturn is still underway and is providing more detailed information on plasma flow and thermal anisotropies in the complex magnetospheres of these planets. Voyager 2 remains healthy, and planning for the Neptune/Triton encounter in August 1989 continues. Voyager 2 is also providing information on the distant solar wind during its cruise from Uranus to Neptune. The Interplanetary Monitoring Platform (IMP-8) remains the only solar wind monitor near Earth; data from IMP-8 continue to be of irreplaceable use for terrestrial studies and as input for comparison with the Voyager and Pioneer spacecraft in the outer solar system. Important results from the mass spectrometer experiment (Dr. Alan Lazarus and Professor Bridge, Co-Investigators) on the Giotto spacecraft were returned from its successful fly-by of Halley's comet in March 1986. These data are currently being studied to understand further the composition of the comet's nucleus and its interactions with the solar wind.

General theoretical work in space plasmas has applied the basic kinetic theory of charged particles moving in a magnetized environment to problems in weak and strong plasma turbulence, plasma instabilities, and collective effects of wave-particle interactions. The specific phenomena considered in this research include: ionospheric-magnetospheric coupling processes, processes by which charged particles are energized in the geoplasma environment, pitch-angle diffusion and precipitation of electrons in the diffuse aurora, wave-particle interactions for unstable ionospheric plasmas involving collisions, sub-visual F-region polar cap arcs, intense electric fields that are detected along auroral field lines during inverted-V events, counterstreaming electrons observed in the supra-auroral region, polar cap particle distributions, supra-thermal electrons and the non-classical polar and solar wind, anomalous geoplasma effects produced by charged beam injections in the ionosphere, radiations produced by moving conducting objects, lower hybrid spikelets in the low altitude ionosphere, and strong plasma turbulence and stochastic heating in the geoplasma environment. Drs. Tom Chang, Geoffrey Crew and Professor Stanislaw Olbert are currently involved in this program.

## PLANETARY STUDIES

### Magellan Venus Radar Mapper Mission (MGN)

CSR participation in this mission involves Professor Gordon Pettengill and Drs. Peter Ford and Joseph Binsack. Professor Pettengill has played a major role in the overall design of this mission, with Dr. Ford involved primarily in the reduction of altimetric and radiometric information to be obtained from the radar instrument. The MGN mission will be launched in November 1989, and should yield a global map of Venus at a resolution of less than a few hundred meters, sufficient to understand many of the geological and geophysical processes that have shaped the cloud-shrouded surface of that planet.

### Mars Observer (MO)

The MO mission is designed to observe those global aspects of Mars which were given short shrift by the earlier Viking and Mariner spacecraft, specifically to produce a high-quality topographic map as well as

other observations that together yield a global picture of that planet's surface composition and geology. CSR will participate in this NASA-approved mission by developing instrumentation for measuring topography (a radar altimeter, jointly with the Jet Propulsion Laboratory), and by helping to interpret the observational results.

#### RELATIVISTIC GRAVITATIONAL ASTROPHYSICS

##### Search for Gravity Waves

Dr. Daniel Dewey earned his Ph.D. degree by searching for impulsive gravitational wave signals taken with the 1.5m-long, gravitational wave prototype interferometric antenna last June. Mr. Jeffrey Livas is analyzing the same data for evidence of periodic signals, using the Cray-2 supercomputer at the University of Minnesota to perform Fourier transforms of over 100 million data points. While testing continues on the 1.5m device, work has begun on a 5m prototype to be installed in a newly-renovated high-bay space in Building 20F.

The CalTech/MIT Laser Interferometric Gravitational Wave Observatory (LIGO) project, whose MIT component is headed by Professor Rainer Weiss, has made significant progress in the past year. Land acquisition has begun in Maine for a 4-km antenna, and plans have been completed for the pre-development studies at both the Maine and California sites. A conceptual design and set of functional requirements for the large antennas have been drawn up in preparation for a detailed engineering design of the system.

##### Cosmology

Instrument testing and characterization for the Cosmic Background Explorer Mission (COBE) has been active, and largely successful, under the guidance of Professor Stephan Meyer over the past year. In addition to its long association with the Far Infrared Absolute Spectrometer (FIRAS) instrument, the MIT group has become more involved with the Diffuse Infrared Background Experiment (DIRBE), which is a photometer designed to measure the absolute diffuse background between 1 and 300 microns in 16 spectral bands. Although the launch date for COBE is uncertain following the Challenger disaster, orbiter construction and testing still proceed according to previous schedules.

The flight cryogenics dewar for our balloon-borne cosmic background anisotropy experiment is being tested. Flight electronics construction is also under way. Because of a balloon launching moratorium, actual flight is not expected until early 1987. This experiment will search for spatial anisotropies of a few parts in  $10^5$ , using four spectral bands between 1 and  $25\text{cm}^{-1}$  and a single external horn with a  $4^\circ$  beam. Two of the four bands will be used to monitor dust emission which is an expected contaminant for the cosmic background signal.

##### Non-Linear Dynamics

The continuation of research in non-linear dynamics by Dr. Paul Linsay was solidified by the award of a three-year grant from the Office of Naval Research for experimental studies of transitions to chaos in non-linear electronic systems. Efforts have been directed at observing the little-understood transitions from quasiperiodicity to chaos. (A quasiperiodic system is one which oscillates simultaneously at several frequencies that are incommensurate multiples of each other.) This group has succeeded in building several circuits that exhibit these transitions, as well as in constructing apparatus to collect and analyze data generated by these circuits.

#### HUMAN FACTORS IN SPACE

##### Spacelab Vestibular Experiments

Experiments on human adaptation to weightlessness continue in the Man-Vehicle Laboratory under the direction of Professor Laurence Young and Dr. Charles Oman. Professor Young's work centers on the visual-vestibular aspects of adaptation, while Dr. Oman's work is directed at Space Adaptation Syndrome (or 'space motion sickness'). Two flight experiments have already been flown on SL-1 and D-1 in 1983 and 1985. At least one future replication is planned.

Experiments on human factors in Space Shuttle/Space Station are being carried out by Professor Stephen Bussolari, also of the Man-Vehicle Laboratory. These experiments were scheduled to be flown on the Earth Observation Mission (EOM) and pertain to optimal ergonomic workstation design.

##### Aerospace Human Factors Research

Professor Bussolari has conducted experiments at NASA/Ames Research Center to study the effect of flight simulator motion on pilot performance and perception of simulator fidelity. The experiments were designed to test new concepts in simulator motion generation that use mathematical models for human spatial orientation. The motion controller acts to minimize the difference in motion perception by the pilot in the simulator versus the actual aircraft. The goal of this research is to provide the simulator designer with

quantitative tools for motion system design and evaluation. Professor Bussolari is also performing research to determine the physiological limits of human athletic performance in long-duration exercise. The understanding of these limits is applied to the Daedalus Project: an effort to design and construct a human-powered aircraft to fly from the island of Crete to the mainland of Greece in celebration of the mythical engineer, Daedalus.

The program of ground-based research on motion sickness and physiological instrumentation continues. MIT has applied for a patent on the pulsed infrared blood circulation monitor developed recently by Dr. Oman and Mr. Walter Cook. This instrument is now in use in collaborative studies at several laboratories, including the University of Rochester Cancer Center, the US Naval Biodynamics Lab (New Orleans) and the NASA Johnson Space Center Biomedical Institute.

GORDON H. PETTENGILL

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## Clinical Research Center

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MIT's Clinical Research Center (CRC) was established in 1964 to provide a facility in which MIT investigators and their collaborators could apply the Institute's expertise in basic biochemical and biophysical mechanisms to the analysis of normal and pathologic processes in humans. Although MIT did not, and still does not, administer a regular teaching hospital to which its CRC might be attached, it was anticipated that sufficient qualified physicians would be involved in the CRC's activities to enable it to take responsibility for all but acutely-ill subjects. Its research activities, over the years, have involved patients with many types of illnesses, as well as normal volunteers (for studies on normal physiology and biochemistry). The past year was a highly productive one for the CRC. Research studies at the Center involved 3796 inpatient days and 1597 outpatient visits under 46 protocols. Bed occupancy averaged 90.9 percent, making CRC one of the the most heavily utilized CRCs in the country.

The CRC is administratively located as a Center within the School of Science. Its principal investigators (i.e., scientists and physicians), authorized to carry out research protocols using its facilities, once these protocols have been approved by MIT's Committee on the Use of Humans as Experimental Subjects (COUHES), include MIT professors; senior research scientists who work exclusively at MIT; and those who also have appointments in local medical institutions. Most of the CRC's present research activities fall within three areas: Metabolism; Neurology/Neuropsychology; and Brain Neurotransmitters (i.e., their control by drugs and nutrients; their involvement in normal and abnormal processes). The CRC's ability to integrate these particular areas has allowed it to become a major international center for the study of disease states having both a metabolic and a neurobehavioral component; e.g., Alzheimer's Disease; Depression; Obesity.

The CRC is administered by a Director, (Professor Richard J. Wurtman), an Associate Director (Professor Vernon R. Young); and six Assistant Directors (Benjamin Caballero, M.D., William H. Dietz, M.D., Ph.D., John Duguid, M.D., Ph.D., Naomi K. Fukagawa, M.D., Ph.D., Robert A. Hoerr, M.D. and Dermot F. O'Rourke, M.D.). The six Assistant Directors are all young physicians who have completed residency training in medical specialties (medicine; neurology; psychiatry; and pediatrics) and have also had advanced research training, usually leading to a Ph.D. degree. The appointment as Assistant Director allows them both to cultivate their own research interests at an important early stage in their career and to serve the CRC (for example, facilitating the conduct of clinical research by other MIT faculty who lack medical training).

During this past year the CRC has expanded its teaching activities by developing an active UROP program (involving 19 students) and by sponsoring two Seminar Series, open to the MIT community, on Depression and on Obesity. The CRC also sponsored, in collaboration with the National Institutes of Health (NIH), a celebration of its 20th anniversary. The afternoon symposium was addressed by, among others, Samuel Thier, M.D., President of the Institute of Medicine at the National Academy of Science; President Paul Gray; and Professor Emeritus Jerome Wiesner. The CRC also provides the locus for pre-doctoral and post-doctoral research projects for 13 students per year.

During the past year the CRC was fortunate to receive two major grants from NIH, in addition to its core support grant of \$2 million per year. These grants provided support for a new computer system (CLINFO) including hardware, software, a systems manager and a biostatistician, and for a Gas-Chromatograph-Mass-Spectrometer laboratory.

Examples of some of the research programs carried out at the CRC are as follows:

I. The long-term objective of the research conducted in the Neuropsychology Laboratory (NL) (Professor Suzanne H. Corkin) is to understand brain mechanism underlying normal human sensation, perception, cognition, action, and affect by studying cerebral disorders. This inquiry relates the specific deficits that follow brain injury or disease to theories of brain organization and to the interplay of cognitive systems. Because each diagnostic group of patients has its own characteristic pattern of lesions, the hypotheses they test vary with patient group.

Recent reports indicate that Alzheimer's disease (AD) patients show deficits in a variety of neurotransmitter markers. Consequently, much of the NL's work on AD has addressed the relation between neurotransmitters and cognition. Initially, they focused on the cholinergic system. A study correlating CSF with clinical measures found that butyrylcholinesterase activity was decreased in AD patients relative to control subjects, and that low butyrylcholinesterase activity was associated with increased severity of dementia, memory impairment, and language disorder. Building on previous work with lecithin, they have completed clinical trials of two agents hypothesized to remediate the symptoms of AD. These agents, piracetam and physostigmine, affect cholinergic neurotransmission. Both studies used crossover designs; the physostigmine trials followed a dose-ranging study. As measured by a comprehensive neuropsychological test



battery, neither piracetam nor physostigmine consistently affect cognition. Currently, the NL is testing the efficacy of monoaminergic treatments for AD by administering clonidine or yohimbine. The use of crossover designs in drug studies required the existence of validated parallel tests forms in order to reduce practice effects. One recent study had the purpose of developing a second form for a standard measure of lexical retrieval. They divided the Boston Naming Test into two 42-item forms and administered both forms to 56 patients with AD and control subjects. Performance on both forms was similar as indicated by mean scores and correlations between scores; further, uncued responses considered in isolation correlated strongly with total scores, suggesting that uncued scores (which require little administration time) may suffice for research purposes. The research program on global amnesia has led to the discovery of dissociations between the learning capacities for different types of material. Recently they reported a contrasting dissociation with AD patients. AD results in cortico-cortical and cortico-limbic but not cortico-striatal lesions; consequently they predicted and found that AD patients were particularly impaired on priming tasks (which depend, they believe, upon cortico-cortical connections) and were particularly competent on motor skill learning (which depends, they believe, upon cortico-striatal connections).

II. William H. Dietz, M.D., Ph.D., is studying energy metabolism in obese and nonobese adolescents. Studies of basal metabolic rate, the thermic effect of food, and the metabolic response to overeating are being conducted. A new technique, using stable isotopes of oxygen and hydrogen, is being applied to measure total daily energy expenditure in free living adolescents and in an inpatient study where adolescents are being overfed. This technique is also being used to study energy expenditure in children and adolescents with cerebral palsy and myelodysplasia. These studies should determine whether difference in energy expenditure account for an increased susceptibility to obesity.

III. During the period of her support (from the NIH) as a Clinical Associate Physician, Naomi Fukagawa, M.D., Ph.D., completed a series of studies designed to explore the interrelationships between the glucose intolerance of aging and alterations in protein/amino acid metabolism. The results of these experiments have been recently published in the Journal of Clinical Investigation and the American Journal of Physiology.

These studies establish, for the first time, the quantitative nature of the relationship between insulin and endogenous protein breakdown in vivo during the postabsorptive state in adult humans. Furthermore, they suggest that the insulin dose-response effect on plasma leucine flux is significantly less in the elderly when compared to the young ( $P < 0.02$ ), at the high physiologic level in insulin. This might imply that nutrient utilization (especially of amino acids) in the absorptive phase, when insulin concentrations are within the high physiologic range, may be reduced in the aged host. Clearly studies must be directed toward examining the interrelationship between insulin-glucose-amino acid metabolism when the supply of amino acids and energy substrates is not limiting.

IV. Harris Lieberman, Ph.D. and Judith Wurtman, Ph.D. have been carrying out a study to measure differences in patterns of calories, protein and carbohydrate intake among young and old adults offered similar foods to eat at meals and as snacks. In addition they are measuring the effects on mood and behavior of consuming meals high in protein or carbohydrate ingested early or late in the day among these two populations of subjects. This study has two objectives: one is to determine whether aging influences the control of food intake and thus whether reported differences in food intake patterns between young and old adults is related to changes in food intake regulation or simply the effect of lifestyle and socioeconomic and health factors. The second objective is to see whether age influences the effects of ingestion of specific macro-nutrients on behavior and ability to perform standardized psychological tasks. To date, they have studied 50 old adults between the ages of 68 and 94 and 35 young adults between the ages of 20 and 35. All have been inpatients at the CRC for two weeks. They expect to conclude the study by late fall.

V. Judith Wurtman, Ph.D. and Dermot O'Rourke, M.D. have measured changes in mood, activity, food intake and melatonin levels in subjects suffering from a mild depressive disorder, Seasonal Affective Disorder. This study began in the fall of 1985 when subjects were admitted to the CRC for a two day measurement period during which their levels of depression were assessed, levels of physical activity measured and food intake from meals and snacks monitored. Twenty-four-hour patterns of melatonin levels were also measured at this time. Subjects returned as inpatients in the beginning of January to participate in a six week study of the effect of a drug, dextrofenfluramine, on their depression, food intake and melatonin levels. They returned for measurements of these factors at the beginning and end of the drug and placebo treatment periods. All subjects were then asked to return in the spring, when the depression is no longer present for a three day inpatient measurement period to obtain information on mood, food intake, activity and melatonin levels.

Although a small subject sample was studied, they were able to distinguish different patterns of mood, food intake and possibly melatonin levels between the fall and spring measurement periods and found in addition that treatment with the drug caused a significant improvement in mood and food intake.

VI. Clinical studies implemented by Professor Richard Wurtman and his associates during the past year have involved neuroendocrinology (the pineal hormone melatonin), neuropharmacology (effects of drugs - like CDP-choline; phosphatidylcholine; and d-fenfluramine used in treating particular brain diseases), and clinical neurochemistry (brain and behavioral responses to foods and other treatments that modify the composition of the plasma).

Circadian patterns of melatonin secretion were examined in, a) normal women at various phases of the menstrual cycle; b) normal volunteers exposed to various environmental lighting conditions; c) people suffering from Seasonal Depression, before and after treatment with the drug d-fenfluramine.

Studies on the mechanism of action of the drug CPD-choline (which is used in Europe to treat people with Parkinson's disease, or those who have suffered brain injuries) showed that the agent produces a very major rise in plasma cytidine levels - in addition to elevating plasma choline level; and parallel studies using rats indicated that both of these plasma changes cause parallel alterations in the brain, and thus probably affect the syntheses of neuronal membranes. A new vehicle for orally administering phosphatidylcholine was tested, and, based on CRC findings, has now been made available to the public.

D-fenfluramine - an anorexic agent that selectively enhances serotonin-mediated neurotransmission - was found, in CRC studies discussed above, also to be an effective anti-depressant drug in people with "serotonin-type" depressions (characterized by hypersomnia, weight gain, and carbohydrate-craving, in addition to depression). Its effects on basal metabolism and on the utilization of energy substrates were also characterized. Finally, a study was conducted on the ability of supplemental tryptophan to suppress the annual weight gain seen in the fall in obese subjects.

During the past year studies conducted by the Nutrition/Metabolism group (Professor Vernon R. Young) have continued to give a major focus to the regulation of quantitative aspects of amino acid metabolism in human subjects of varying adult age. These investigations have exploited the use of stable (non-radioactive) isotope tracers which can be safely and repeatedly used in direct human studies and for which the CRC is recognized world wide as a leader in this area of human metabolic investigation. These studies have explored principally the impact of dietary changes on human amino acid metabolism and the relationship between human aging and amino acid metabolism, with particular reference to the anabolic action of insulin and the changes in body composition that occur with advancing old age.

Major highlights of the research include, 1) the development of a new approach for estimation of the kinetic status of amino acid metabolism under varying conditions of amino acid intake. These studies have led to significant improvements in our estimations of the quantitative requirements of amino acids for health maintenance. 2) New insights have been gained about the regulation of methionine metabolism in man. This research has significance with respect to the potential improvements in the treatment of patients who suffer from genetic diseases of methionine metabolism. 3) The role of the so-called nutritionally dispensable (non-essential) amino acids in human metabolism has been further clarified, particularly with respect to the regulation of proline biosynthesis *in vivo*. Our studies are the first to demonstrate product feedback regulation of proline synthesis in the intact human subject. From this research we postulate for adverse conditions, such as in human trauma, that proline becomes a conditionally essential amino acid metabolism and, thus, should be included in amino acid mixtures designed for nutritional support of hospitalized patients. Also, this research is shaping current concepts of the nutritional significance of amino acids in food protein sources. 4) Changes in the sensitivity of peripheral tissues (e.g., muscle) of amino acid metabolism to insulin action account for the erosion of body protein mass with advancing adult age. The loss of body protein mass may well contribute to the characteristic decline during aging in the ability of the organism to withstand unfavorable stress, such as physical trauma and infection. 5) New mathematical models are being developed to improve an understanding of the role played by the splanchnic organs (liver and intestines) in the utilization of meal-derived amino acids. This research combines compartmental modelling procedures with the stable isotope tracer techniques established at the CRC and has resulted in a more precise assessment of the way by which the major body organs integrate amino acid metabolism and achieve homeostasis under various pathophysiological states.

RICHARD J. WURTMAN

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## Experimental Study Group

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The Experimental Study Group finished its seventeenth year of alternative academic instruction for undergraduates at MIT. ESG continues to provide its students with the opportunity to study core freshman subjects by a variety of methods, including tutorials, seminars, and independent study. Almost half of the freshmen joining ESG this year said they did so because of the opportunity for self-paced study, 25 percent for the style of teaching and small class size available, and 14 percent for the community aspects of the program. These figures have remained relatively constant over the past four years.

### STUDENT STATISTICS

ESG enrolled 42 new freshmen, 4 sophomore transfer students, and 28 ESG upperclassmen for one or more terms this year. Forty-three percent of the entering freshmen were women (the highest percentage in ESG's history), 14 percent were minority students, and 12 percent were international students. These figures are once again higher than the corresponding figures for the MIT freshman class (27 percent, 9 percent, and 6 percent respectively). The 39 sophomores who had been in ESG as freshmen achieved a median grade point of 4.3, compared to a 4.1 median grade point for the entire MIT sophomore class. This is the sixth consecutive year in which ESG sophomores achieved a higher median grade point than their counterparts in the regular curriculum. We are particularly pleased with the performance of our students since the scholastic ratings of freshmen who joined ESG from 1982 to 1986 (based on material in their admission folders) do not differ significantly from the average scholastic ratings of all incoming freshmen for those same four years.

Forty-three percent of the 130 ESG upperclassmen currently registered at MIT are majoring in science, almost twice the percentage of all MIT upperclassmen majoring in science (23 percent). Interest in majoring in science has risen among ESG students for the past three years (33 percent in the Class of 1986, 39 percent in the Class of 1987, and 56 percent in the Class of 1988). The percentage of ESG freshmen who anticipate majoring in science when they enter MIT is usually lower than the actual percentage of those students who go on to major in science as upperclassmen. For example, 41 percent of the ESG Class of 1988 indicated an interest in majoring in science as freshmen versus 56 percent who actually ended up as science majors.

### STAFF AND FACULTY

Professor J. Kim Vandiver, Director, and Holly Sweet, Associate Director, oversaw the administration of the program in consultation with the ESG Faculty Advisory Committee. The Committee is composed of representatives from the Departments of Chemistry (Professor Alan Davison, Chair), Mathematics (Professor David Anick), Physics (Professor Lee Grodzins), Humanities (Professor Arthur Kaledin), and the School of Science (Professor Gene Brown). Professor Vandiver is also currently Associate Chairman of the Faculty. Ms. Sweet was appointed a lecturer in the School of Science this year and taught two subjects at ESG, an undergraduate seminar in the fall and a humanities subject in the spring. Other members of the ESG humanities staff included Professor Gary Marx (Department of Urban Studies and Planning), Fanny Howe (Writing Program), and graduate student Lee Perlman (Department of Political Science). The physics staff included Professor John King, Professor Emeritus Robert Halfman, Dr. Peter Dourmashkin, Dr. Yekta Gursel, Craig Watkins, and graduate student James Mahoney. The mathematics staff, headed by Dr. Mark Haiman in his third year at ESG, included graduate students W. Montgomery McGovern and Kathryn Hess. For the first time two undergraduate tutors, Donna Giesman (Class of 1986) and Seth Brown (Class of 1987), were the official teaching assistants for ESG sections of 5.11 (Principles of Chemical Science) and 5.12 (Organic Chemistry). Their competency and commitment was outstanding, measured not only by student assessment of their teaching but also by superior student performance.

Twenty-two other ESG upperclassmen assisted the ESG staff in tutoring freshmen and sophomores in a variety of subjects, primarily the core freshman subjects in mathematics and physics. The extensive use of undergraduate tutors at ESG has helped us maintain a favorable staff/student ratio and greater availability of self-paced tutorials for our students. We are continuing to support the efforts of our tutors with regular training sessions conducted by our staff.

### ACADEMIC DEVELOPMENTS

Interest in expanding the academic and pedagogical options available to undergraduates at MIT is always high at ESG, and this year was no exception. Under the guidance and enthusiasm of Professor King, there was a reemergence of a hands-on physics lab at ESG which is currently being expanded to meet the needs of first year physics students. We were fortunate in obtaining the teaching services of Dr. Gursel from the Artificial Intelligence Laboratory to teach an ESG section of 6.001 (Structure and Interpretation of Computer Programs). The ESG Project Athena workstations were used in conjunction with this course.

This spring three of our students developed a proposal to teach an undergraduate chemistry laboratory for freshmen, 5309 (Chemistry Demystified: A Laboratory for Beginners), which was approved by the Department of Chemistry. The students will be working on curriculum development for the summer and will be teaching this seminar in the fall in the regular curriculum.

ESG has been offering several undergraduate seminars each year as a regular part of its curriculum. This year we again offered SEM051 (Sex Roles and Androgyny) in the fall and SEM056 (Engineers and Scientists in the 80s: A Personal Look) in the spring. We were very pleased with the student response to both seminars: as one freshman said in her end of term evaluation, "I just wish that more students could be exposed to this kind of thing!"

In response to increasing pressure from our upperclassmen for more opportunities for academic involvement in ESG, two different proposals were developed in ESG during the year and were approved by the Committee on Curricula. The first proposal establishes an ESG special topics number which allows our students to pursue subjects for credit which aren't covered under an already existing subject number. One of our freshmen took advantage of this credit in the spring to develop a prototype for an undergraduate seminar on communication. The second proposal allows our juniors and seniors to continue to take humanities subjects in ESG, provided that they take at least half of their humanities requirements in the regular curriculum. ESG typically has a greater percentage of its upperclassmen majoring in humanities and social science subjects than is true overall at MIT. We believe that this proposal is one way of serving the educational needs of those students and providing our freshmen with greater exposure to humanities majors at MIT.

After initial meetings with the Provost's Office, the administrative staffs of ESG, Concourse, and the Integrated Studies Program met regularly throughout the spring to develop new ideas in undergraduate education at MIT. We are currently in the process of designing a series of hands-on workshops and labs for freshmen which will be given for credit during IAP in January of 1987. These subjects will allow students to work closely with faculty and fellow students in obtaining practical experience in a variety of fields, including writing, electrical engineering, drama, and physics. We are excited about the prospect of expanding the ways in which students are educated at MIT and will continue our efforts to use our program as a testing ground for these ideas in the future.

HOLLY B. SWEET  
J. KIM VANDIVER

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## George Russell Harrison Spectroscopy Laboratory

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The George Russell Harrison Spectroscopy Laboratory is engaged in fundamental and applied research in modern spectroscopy for the purpose of advancing our knowledge of the structure and dynamics of atoms and molecules and the properties of liquids and solids. Techniques include the use of lasers, microcomputers and other data acquisition systems.

An interdepartmental laboratory, the Spectroscopy Laboratory encourages participation and collaboration among members in the various disciplines of science and engineering. This past year there has been participation from several MIT departments including Chemistry, Physics, Biology, Electrical Engineering and Computer Science, Chemical Engineering, and Mechanical Engineering. Outside collaborations with academic, government and industrial organizations have further strengthened the interdisciplinary research activities of the Laboratory.

The Laboratory is directed by Professor Michael S. Feld of the Department of Physics. Professor Jeffrey I. Steinfeld of the Department of Chemistry and Dr. Ramachandra R. Dasari, Principal Research Scientist in the Laboratory, are Assistant Directors.

This past year has been one of continued growth in resources and personnel, and of national recognition for the Laboratory. A new Biotechnology Resource Center for research in lasers and medicine was established under the support of the National Institutes of Health; it will function in parallel with the NSF-supported Laser Research Center. Dr. Michael Otteson was promoted to the research staff, and Carol Campbell to the post of Office Manager. In January the MIT Laser Research Center received the Special President's Award of the International Society for Optical Engineering (SPIE) for its contributions to the advancement of laser technology.

### MIT Laser Research Center

The MIT Laser Research Center, a National Science Foundation Regional Instrumentation Facility housed in the Spectroscopy Laboratory, is now in its sixth year of operation. The Center enables researchers from academic, industrial, and other types of institutions to pursue research in broad areas of laser spectroscopy and dynamics, to develop new types of coherent sources and techniques, and to perform diagnostic studies of various substances and materials. Its unique facilities, which include a broad range of lasers and ancillary equipment, constitute one of the largest and best-equipped centers devoted to spectroscopic research. They are made available free of charge to qualified scientists and engineers from MIT and outside organizations.

Current available equipment includes continuous wave (CW) and pulsed dye lasers in the visible and ultraviolet, CW and pulsed CO<sub>2</sub> lasers, a tunable diode laser spectrometer, and a laser Raman spectrometer. There are over 40 major laser systems. All are interfaced with microcomputers which control experiments and collect and analyze data. Auxiliary equipment includes a transient digitizer and an optical multichannel analyzer. This past year 37 new and continuing projects were conducted at the Center in atomic, molecular and solid state physics (12); physical and inorganic chemistry and biochemistry (16); and applied sciences (9). Twenty two of these were initiated by MIT Core and other faculty, 12 by researchers from other academic institutions, and 3 from industry and government laboratories. Scientists from Brazil, Argentina, China and France worked at the Center. Results of these projects have appeared in 92 papers, conference reports and theses.

### MIT Center For Research In Lasers And Medicine

The MIT Center For Research In Lasers And Medicine was established in the Spectroscopy Laboratory in September as a Biotechnology Resource Center of the National Institutes of Health. Biomedical applications of lasers and laser spectroscopy promise to change the face of medicine as it is currently practiced. The initial success of lasers as

optical scalpels has prompted much interest from physicians, scientists and engineers, and has led to an awareness that fundamental understanding of laser-tissue interactions is essential for further progress in areas such as micromachining of tissue, photochemical and photodynamic therapies, and tissue diagnostics. For example, laser light, delivered to an interior part of the body via a fiber-optic bundle, can excite tissue fluorescence which can be collected and analyzed remotely to differentiate tissue type, normal from diseased tissue, the presence of chemicals and drugs, etc. With the aid of image processing techniques, such spectral fingerprints can be used to construct real-time spectro-optic images of internal body parts.

Once the new space is renovated and the equipment is in place, the new Center will be used to conduct research in this and other forefront areas of lasers and medicine. Both core research and collaborative projects will be supported. In addition, the Center will provide its resources free of charge, on a time-shared basis, to medical researchers who wish to pursue research in this important new field. Professor Feld will direct the new Center, Dr. Dasari will be Project Coordinator, and Dr. Carter Kittrell of the Spectroscopy Laboratory will serve as Research Coordinator.

#### RESEARCH HIGHLIGHTS

Professors Robert W. Field and James L. Kinsey and Drs. Jean Paul Pique and Charles Hamilton, all of the Department of Chemistry, have used stimulated emission pumping (SEP) to study highly excited vibrational levels of acetylene and hydrogen cyanide. The spectra obtained, when analyzed in terms of traditional spectroscopic patterns and modern statistical measures of quantum ergodicity, provide information about dynamical processes such as isomerization and intramolecular vibrational randomization (IVR). Huge quantities of high quality spectra are required in order to obtain meaningful information from the statistical diagnostics. Microprocessor control of the SEP spectrometer has led to a tenfold increase in data rate and to the discovery of multiple time scales for IVR. An additional improvement in resolution and dynamic range is being sought by a new pulsed/CW SEP scheme which has necessitated the installation of two new laser systems in the Spectroscopy Laboratory.

Professors Field and Kinsey are collaborating with Professor Richard Redington of the Texas Technical University Department of Chemistry on SEP studies of H-atom tunneling in internally hydrogen-bonded molecules such as tropolone, pyruvic acid and oxalic acid. Due to the complexity of the spectra of such molecules, it is necessary to utilize the rotational cooling provided by a supersonic jet apparatus. The goal is to determine the coupling of heavy atom motions (especially those remote from the H-bonding moiety) to the barrier to H-atom tunneling. These H-atom tunneling motions are prototypes of the sort of large amplitude motions that occur in isomerization, chemical reactions and fluxional molecules. Initial fluorescence excitation spectra of tropolone have been obtained, and presently an attempt is in progress to record the first SEP spectra of molecules in a supersonic jet.

Professor Robert Field is measuring the reorientation of the total angular momentum,  $\vec{J}$ , which accompanies rotationally inelastic collisions. Individual  $J$ ,  $M_J$ ,  $\Lambda$ -doublet components of the  $\text{CaF } A^2\Pi_{1/2}$  state are initially prepared and subsequently probed by an optical-optical double resonance (OODR) scheme utilizing two cw dye lasers. Small deviations of the measured  $J$ -reorientation rates from theoretical predictions are due to the presence of hyperfine structure. A new series of experiments, in which a 1000 Gauss magnetic field allows complete hyperfine state selectivity in the preparation and probe states of the OODR experiment without affecting the collisional process, will provide an unprecedentedly detailed picture of the collisional reorientation of  $\vec{J}$  and  $\vec{F}$  both in laboratory and body-fixed coordinate systems.

Professor David Adler of the Department of Electrical Engineering and Computer Science has investigated characterization of hydrogenated amorphous silicon deposited by low pressure RF glow discharge decomposition of silane. In these studies Raman spectroscopy is used as a probe to study the extent of amorphous and crystalline nature of the samples.

Professor Alan J. Grodzinsky and Dr. Aryeh M. Weiss, both of the Department of Electrical Engineering and Computer Science, are continuing their investigation of cross-linked polyelectrolyte-gel membranes whose permeability to neutral or charged solutes can be controlled in real time by chemical or electrical stimuli. Recently, large ( $\times 50$ ) reversible permeability changes have been demonstrated. These changes depended critically on solute size and charge, as well as membranes composition. Work is now in progress to quantify the parameters which determine membrane performance. The experimental protocols developed at the Laser Research Center will be used in

conjunction with a theoretical continuum model developed by Dr. Jeremy H. Nussbaum of the Department of Electrical Engineering and Computer Science to optimize membranes for applications such as chemical separations and drug delivery.

Professor Alan Davison of the MIT Department of Chemistry has continued his research on resonance Raman spectroscopy of technetium complexes. A metal to ligand vibrational mode of technetium-labeled metallothionein, a metal storage protein, was observed and identified by comparison with a variety of model compounds. Resonance enhancement allowed detection at concentrations as low as ca.  $10^{-5}$  molar. Raman spectroscopy was also utilized to characterize a series of technetium dimers with aminocarboxylate ligands. These dimers possess strong metal-to-metal bonds and bridging oxo ligands.

Professor Daniel Kleppner of the Department of Physics continues his investigations of the interaction between an atom and a magnetic field. The diamagnetic shift is comparable to the atomic energy level spacing when the atom's valence electron is far from the nucleus. Recently, lithium atoms were excited to states as high as 60p in a thermal atomic beam using multiphoton CW dye laser excitation. These Rydberg states were detected by electric field ionization. The present technical problem is a stray electric field, which seems to arise from surface charges inside of the interaction region. This field causes undesirable distortion of the spectrum involving high Rydberg states.

Professor Stephen J. Lippard of the Department of Chemistry is studying the Raman spectra of model compounds for polymetallic iron centers in biology. Three binuclear complexes have been examined, u-oxobis(u-acetato)-diiron(III) and its hydroxo-bridged and phosphodiester-bridged analogs. Although the Fe-O stretching force constants for the three compounds remains approximately equivalent, the stretch-stretch interaction constant changes in a manner reflecting the Fe-O-Fe bridge-bond angle. This variation can be explained by orbital overlap considerations. Raman spectroscopic studies of tetranuclear and undecanuclear iron complexes have been initiated, and will be extended once UV excitation capabilities are available.

Professor Regis M. Pelloux of the Department of Materials Science and Engineering is employing pulsed Nd:YAG laser radiation to introduce small surface defects in nickel-base superalloy specimens to serve as initiation sites. These sites, which are small in size ( $\sim 10$   $\mu$ m), dictate the use of laser radiation. The objective of this research is to establish criteria for lifetime predictions for critical jet engine components.

Professor Alexander Rich and Drs. Andrew H.J. Wang and Gary Quigley, all of the Department of Biology, are studying the anthracycline antibiotics daunomycin and the closely related adriamycin for use in the treatment of human carcinomas. More recently they have extended their studies to include the quinoxaline antibiotics echinomycin and triostin A, which are also anti-tumor agents. In an attempt to study the manner in which these drugs interact with DNA, they have been co-crystallized with various fragments of DNA of different lengths. The crystal structure of several drug complexes has been solved. The complexes with the quinoxaline antibiotics revealed a remarkable conformational change with the introduction of novel hydrogen bonding interaction between the DNA bases.

A number of chemically similar compounds have also been either isolated or synthesized, and the effects of specific chemical substitutions in these drugs have been correlated with biological activity. Professor Rich and his colleagues are currently comparing the structures of several daunomycin derivatives complexed to other DNA sequences. By solution of these structures, the specific chemical alterations and their effects on complex formation, as well as on the mechanism of action of the drug can be studied.

Professor Henry I. Smith of the Department of Electrical Engineering and Computer Science is investigating the use of short wavelength (193 nm) excimer laser light to make very fine period sub-100 nm gratings for use as diffraction elements in the soft x-ray energy range. Gratings with a period of 100 nm would give about a factor of two improvement in the energy resolution of diagnostic instruments such as time-resolved streak camera spectrometers. These x-ray diagnostic instruments are important tools in laser fusion, laser plasma physics, and x-ray laser research.

Professor Steinfeld and his co-workers in the Chemistry Department have used Coherent Anti-Stokes Raman Spectroscopy (CARS) as a probe for molecules pumped by high-intensity CO<sub>2</sub> laser radiation. Ozone, sulfur hexafluoride, and chloroethane have been investigated. The intensity of the ground-state CARS signal is decreased by

infrared multiphoton excitation (IRMPE), but signals at new vibrational origins do not appear. These observations are interpreted in terms of a rate equation model for IRMPE, modified to take vibrational redistribution into account.

Professor Mark S. Wrighton of the Department of Chemistry is continuing his studies of resonance Raman spectroscopy of photo-excited states and photogenerated transients. During the past year he completed a study to determine the ligand of electron localization in the lowest excited electronic state of mixed ligand complexes of ruthenium(II). Current studies are focused on the characterization of the dynamics of electron transport properties of multi-component redox molecules that have been shown to exhibit a kind of rectification like that crucial to the function of the natural photosynthetic apparatus. The ultimate objective is to demonstrate light-driven electron transfer processes using such multi-component molecules anchored to the surface of conducting solids.

Professor Ioannis V. Yannas of the Department of Mechanical Engineering is utilizing small-angle light scattering from dermal tissue to develop a quantitative method to evaluate regenerated dermis. The results from the observed differences between scar and normal dermis have enabled evaluation of the quality of neodermal structures grown on guinea pigs when implanted with artificial skin grafts.

Professor Michael S. Feld of the Department of Physics and Drs. Dasari, John E. Thomas and Michael Otteson of the Spectroscopy Laboratory continue their research on laser-induced nuclear orientation (LINO), which has been successfully applied in a table top experiment to measure the laser-induced anisotropy in the gamma ray decay distribution of short lived (1 us)  $^{85\text{m}}\text{Rb}$  atoms. Present experiments to obtain sub-Doppler narrow tunable gamma resonances are in progress. In addition, these sub-Doppler LINO resonances provide a potential new method of producing tunable narrow band polarized gamma rays.

Professor Feld and Drs. Thomas and Dasari have investigated a variety of quantum transport phenomena in atomic and molecular vapors using laser photon echo techniques. Experiments have studied quantum superposition state scattering, for which there is no classical analog. Results include direct inversion of two pulse echo data to obtain two-level optical radiator velocity changing collision kernels with a few cm/s resolution; magnetic state scattering kernels for isolated multipole moments; and development of a new tunable energy compensation technique to resolve velocity changes accompanying collision-induced molecular radiator reorientation.

Professor Feld and Dr. Thomas are investigating two level optical superfluorescence (SF) in a cavity to study quantum fluctuations in a single longitudinal and transverse mode of the optical field, as well as the SF quantum initiation process. A new type of high intensity frequency-narrow atomic beam has been developed for this purpose. Both single atom SF and multiple atom cooperative effects are under study.

Professor Feld and Dr. Kittrell are engaged in biomedical research to understand the mechanism of laser ablation of tissue, for laser microsurgery. A theory of thermal laser ablation has been formulated, and the dosimetry and damage predictions have been confirmed in experiments in human cadaver arteries using blue-green light. In addition, laser-induced fluorescence has been used to distinguish plaque, blood, and normal artery wall, and then to construct spectral "maps" of the interior of the artery. In parallel with this work, Drs. Feld and Kittrell and Dr. Barry Sacks of Leonard Morse Hospital, Natick, MA., and Drs. John Kramer, Floyd Loop and Bruce Lytle of the Cleveland Clinic Foundation are engaged in a program to develop a clinical system for diagnosing and treating atherosclerosis using laser light delivered percutaneously through optical fibers.

MICHAEL S. FELD



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## Laboratory for Nuclear Science

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The Laboratory for Nuclear Science (LNS) provides support for research by faculty and research staff members primarily in the fields of basic nuclear and elementary particle physics, including the activities of the Center for Theoretical Physics in these fields. LNS also supports some projects involving application to medical physics of experimental techniques developed through its primary activities. In addition, it provides a computing facility for its program. The primary experimental programs are in three areas. The largest local effort is in intermediate energy nuclear physics, centered at the Bates Linear Accelerator Center in Middleton, Massachusetts. The Laboratory also has a users group at the Los Alamos Meson Physics Facility (LAMPF). In high energy physics, there are major projects in the US at Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois; and the Stanford Linear Accelerator Center (SLAC) in Palo Alto, California. A third field is relativistic heavy ion physics with activities at Brookhaven National Laboratory (BNL). Abroad there are experiments at the German Electron Synchrotron Laboratory (DESY) in Hamburg, Germany, at the European Center for Nuclear Research (CERN) in Geneva, Switzerland, and at the Gran Sasso Laboratory in Italy.

### Intermediate Energy Nuclear Physics

The principle activity in this field is centered at the Bates Linear Accelerator Center, which is operated under the joint auspices of LNS and the Department of Energy. The Laboratory serves the national community, providing intermediate energy electron and photon beams for precision studies of nuclear structure and for reaction studies aiming at fundamental understanding of the nuclear force. The intermediate energy research programs of MIT faculty and research staff, both at Bates and at off-campus facilities, are described below; Bates developments are described in a separate contribution.

Twenty-six MIT graduate students were associated with the intermediate energy research program during the past year. One student, William Burger, was awarded the Rosen Prize, given annually for thesis research carried out at the Los Alamos Meson Physics Facility. A recent graduate, Charles Hyde-Wright, was awarded the Demos Prize, given annually for doctoral research carried out at and outstanding contributions to the Bates Laboratory.

A large fraction of the faculty and senior research staff participating in intermediate energy nuclear physics carried through at Bates during the past year a difficult set of experiments on the tritium nucleus. The aim of the program is an extensive and precise characterization of the electromagnetic structure of three-body nuclei. This system is rather special in permitting a particularly sharp confrontation with theoretical expectations while still possessing a structure rich enough so as to bear upon a number of important issues. The technical challenge arose principally from the need to contain a large inventory of radioactive tritium in a geometry appropriate for precision experiments. Analysis of elastic data has already provided an important test of meson contributions to the structure of tritium and helium-three. The role of three-body forces and of modified nucleon structure in the nuclear medium will be addressed in the more complete analysis. The inelastic data and the precision of the elastic data are unique to the Bates experiment.

Precision electron scattering studies of the structure of more complex nuclei have continued. For example, the magnetization distribution in oxygen-17 has been resolved to an unprecedented short distance scale.

A major effort has been and will continue to be focussed on studying nuclear response to large energy transfer. A benchmark coincidence study of protons knocked out of the nucleus by electrons is underway. The goals of the program include understanding single-nucleon motion in the nucleus, modifications of nuclear structure in the medium, and contributions to the electromagnetic current arising from the close interaction of two (or more) nucleons. The first results of the measurement program are extremely provocative. For example, a surprisingly large fraction of the nuclear response appears to involve the direct ejection of more than one proton. Further, even qualitative features of the nucleon electromagnetic coupling, such as the ratio of coupling strength with momentum transfer, appear to be modified in the nuclear environment. These results are widely held to be associated with nucleon substructure, but a far more extensive experimental characterization is needed for guiding quantitative theoretical approaches.

Direct emission of single protons by intermediate energy photons has been studied. An interesting scaling phenomenon has been found in comparing data for different energies and may provide the clue needed for extracting information about the probability for finding nucleons with very large momentum in the nucleus. This in turn would be very instructive for understanding the short-distance structure of the nucleus. A large effort is underway to clarify this by examining the same process for neutron emission. This is a difficult task but the first data should be available in the coming year.

A unique test of the unified theory of electromagnetic and weak interactions, to be carried out at Bates, is in preparation. The experiment aims to measure the very small asymmetry expected ( $\sim 10^{-6}$ ) in elastic scattering of right- and left-handed electrons from nuclei. A major obstacle for such an experiment is the need to produce a beam of polarized electrons; this has recently been accomplished after a long development program.

Another experiment in preparation, again involving many of the faculty and senior research staff, aims to measure the monopole and quadrupole charge distributions of the deuteron for the first time. It is perhaps surprising that these fundamental quantities are not yet known but, with the completion of ongoing upgrades, the Bates accelerator will be the first with the required combination of energy, intensity and duty factor to permit the measurement to be made in an interesting regime. There are many theoretical speculations about the short-distance structure of these charge distributions and the data, which hopefully will be taken by the end of 1987, are awaited eagerly.

Complementary to the Bates experiments are investigations by the MIT group at other accelerator facilities. The largest program is that examining selected pion-induced reactions at the Los Alamos Meson Physics Facility. This program aims at isolating pion interactions with nucleons and with nucleon clusters in the nuclear medium, particularly in the energy regime corresponding to the lowest excitation of the nucleon. In doing so, one expects to learn how internal nucleon structure affects the strong interaction of baryons. Both pion annihilation and charge-exchange reactions are being examined. The former have proved rather convincing in revealing many-body effects in the annihilation process, a process intimately connected with the origin of the nuclear force. Single and double charge exchange studies are isolating the pion interaction with nucleon pairs. Such a unified approach encompassing scattering from the absorption on nucleon clusters is essential for advancing our understanding of strong interaction dynamics.

Another group is collaborating with Brookhaven physicists in a study of hypernuclei. These are nuclei in which one of the nucleons is replaced by a particle carrying strangeness (i.e., one of the light quarks which make up ordinary matter is replaced by a heavier, strange quark). Both  $\Lambda$  and  $\Sigma$  hypernuclei have been studied, leading to an experimental determination of the interaction strength of strange particles with nuclear matter. Electromagnetic transitions in  $\Lambda$ -hypernuclei are being studied, particularly with a view towards reliable measurement of the  $\Lambda$  spin-orbit force. In addition, the group continues to investigate new methods for the detection of solar neutrinos.

#### Experimental High Energy Physics

The Electromagnetic Interactions (EMI) Group is engaged in two efforts in experimental high energy physics: one at the highest existing electron-positron colliding beam accelerator, PETRA, in Hamburg, Germany, and the other at the Electron-Positron accelerator, LEP, under construction in Geneva.

The work at LEP: The group is leading a large construction effort, which involves 380 Ph.D. physicists from 12 nations, to build a large, accurate detector to measure photons, electrons, and muons precisely. The experiment is the first large-scale collaboration between physicists from the Soviet Union, the People's Republic of China, the United States, and Europe. The construction of this experiment is proceeding according to schedule and will be ready for data-taking by the time of the first LEP beam scheduled for the end of 1988. The purpose of this experiment is to understand the origin of the masses of elementary particles.

The work at PETRA: After its discovery of gluons, this group has concentrated on the study of the properties of gluons to increasingly high orders of accuracy. Of particular importance is the group's recent work on the determination of the second order coupling constant between gluons and quarks, showing that the general theory of strong interactions between quarks and gluons is understood. In addition, they have shown that the expected sixth quark, known as the top quark, is much heavier than previously expected. Their measurement of direct muon production has yielded a much better understanding of the ways in which different quarks transform themselves into ordinary subatomic particles. The group plans to continue to take data with a new high resolution vertex chamber to study the lifetimes of new heavy particles.

#### UAI Experiment

The UAI Group is studying proton-antiproton collisions at the CERN Sp $\bar{p}$ S Collider in Geneva, Switzerland. The center of mass energy range is 200 GeV to 900 GeV. The physicists in UAI are investigating many exciting phenomena in particle physics. After its discovery of the  $W^\pm$  and  $Z^0$  particles, the intermediate vector bosons predicted by the standard electroweak model, this group made a detailed analysis of the production properties of these particles. One of the many results of this study was an upper limit on the number of light neutrino species in the universe. Results of the analysis of the production of heavy quarks (charm and beauty) include the possible observation of mixing of the  $B^0$  and  $\bar{B}_s^0$  mesons; such mixing has only been observed in the  $K^0 - \bar{K}^0$  system. A search for more fundamental particles such as a sixth quark (top), a new heavy lepton, and supersymmetric particles is taking place.

The physics research possibilities will be increased by the advent of a new antiproton accumulator (ACOL) at CERN (which will increase the data sample by a factor 10) and by upgrading the UA1 detector to improve the identification of particles and allow measurements of their properties.

The Accelerator Physics Collaboration (APC) is conducting experimental research on the nature and interactions of photons, hadrons, and neutrinos. An experiment at FNAL, completed three years ago, was designed to study how hadrons made up of one set of quarks generate hadrons with other types of quarks or other combinations of the same type of quarks. For this study, a unique device was developed that identifies each particle produced. The device, called CRISIS, worked well and should give information never previously available. The data from this experiment are currently being analyzed. Several papers have been published and six students have received their Ph.D.'s from this work. Studies are continuing on the question of hadron-nucleus collisions. This topic is of great interest, not only for high energy physics, but also for heavy ion physics.

The group has taken data at FNAL in the world's highest energy neutrino beam. This experiment used a holographic bubble chamber which was designed for the tau neutrino experiment described below. In this experiment one will be looking at a new domain in neutrino physics where new phenomena might be found.

A future experiment has been approved for running at FNAL in 1989, apparatus for which is being designed and built now. The goal of the experiment is to search for a hitherto undiscovered particle, the tau neutrino. Proof or denial of its existence will have major theoretical consequences. This experiment will use a new technique being developed explicitly for it, the holographic photography of a bubble chamber. The technique will provide a factor of ten improvement in resolution over conventional bubble chamber pictures. As noted above, the chamber has been built, is currently operating and meets all specifications. All of these experiments are being done in collaboration with a consortium of universities in Japan, China, Israel, Italy, France, and the United States.

The experiment in Gran Sasso Laboratory, which is the world's largest underground laboratory, will study particle physics problems and astrophysics problems. The particle physics problems are related to new radiation coming from Cygnus X-3. These studies might prove that Cygnus X-3 is a quark star which is emitting a new form of matter not yet seen on earth. In addition, this experiment can make the best measurement on the neutrino oscillation problem. From the point of view of astrophysics the detector will study the production of solar neutrinos by the sun, the yearly rate of collapsing stars in the universe and possible point sources emitting high energy neutrinos.

The Counter Spark Chamber (CSC) Group in a collaborative effort has constructed a major new detector for high energy neutrinos at FNAL. The initial experimental program for this apparatus is the detailed study of the weak neutral currents predicted on the basis of the electro-weak theory and discovered experimentally several years ago. An experiment has been performed to study the nucleon structure functions associated with the neutral weak current. This detector, consisting of 350 tons of instrumented target material followed by a muon spectrometer, is now being used for a continuation of these studies with the newly commissioned Tevatron. The group is also collaborating in the construction of a high energy muon scattering facility at Fermilab which will be used with the Tevatron to study nucleon structure as well as the dynamics of quark jets in nuclear matter. This experiment is scheduled to begin taking data during 1987.

The major long term focus of the group is in the construction and exploitation of a new "state of the art" particle detector for use at the Stanford Linear Collider (SLC). This detector called the Stanford Large Detector (SLD) is now under construction and the CSC Group has a major responsibility for construction of the warm iron hadron calorimeter and muon detector. Installation of the detector will begin in 1987 and data taking will begin at the end of 1988.

The physics that will be pursued with this device is very exciting, and includes studies of the intermediate neutral boson ( $Z^0$ ), search for the Higgs meson, and search for new leptons and super symmetric particles. For this reason a second group is also involved.

#### Lepton Quark Studies (LQS)

The LQS group is heavily engaged in the development and construction of the Central Drift Chamber for the SLD detector to be used in the SLAC (Stanford Linear Accelerator Center) Linear Collider (SLC).

#### Relativistic Heavy-Ion Physics

Nuclei are normally kept apart by strong Coulomb repulsive forces. When nuclei collide with sufficient energy to overcome that barrier, a richness of phenomena is observed whose study has given us deep insights into nuclear properties. For almost two decades the "Heavy-Ion Group" at MIT has carried out these studies in order to investigate the properties of nuclei at the limits of their stability. How much angular momentum can a nucleus have before it flies apart? How many protons can it contain? How many neutrons? How far apart can the constituents be and still be part of the nucleus? Can nuclei form nuclear molecules?

The imminent ability of accelerators to produce heavy nuclei with energies a thousandfold in excess of the Coulomb barrier holds the promise of studying nuclei at the limits of their density and energy. The interaction of extreme relativistic ions with targets as heavy as uranium is expected to produce matter densities and energy densities almost an order of magnitude greater than normal. New phases of nuclear matter may appear. In these dense states a plasma may be formed from the quarks which make up the nuclei and the gluons which bind the quarks. The interactions at close quarters may break the bonds which confine the quarks and thus set them free. It is to these studies that the heavy-ion group has now turned its attentions.

The studies of these phenomena will begin with beams of 500 GeV sulphur nuclei produced at Brookhaven National Laboratory. Neither the energy nor the mass of these initial beams is expected to be high enough to produce a quark-gluon plasma, but the conditions will still be an order of magnitude more extreme than any hitherto observed under controlled conditions. In the coming years we will accelerate heavier and heavier nuclei to higher and higher energies so as to reach further into the extremes of mass and density, extremes which will eventually approximate those that are conjectured to have occurred in the early stages of the expanding universe.

#### Applications of Nuclear Techniques

The Medical Imaging Group has continued its collaboration with similar groups from Brigham and Women's Hospital (BWH), Harvard Medical School (HMS), and Massachusetts General Hospital (MGH) in the development of new clinical instruments. A prototype positron emission tomography (PET) system is under test at BWH and a larger unit for cardiac imaging is under construction at MIT. As part of this project we have also developed new reconstruction algorithms for three dimensional imaging which may have also developed a gas scintillation camera for cardiac imaging which is presently under test at MIT. The present unit has a factor of three better energy resolution compared to present instruments and improved data rate capability. This should result in increased reliability in cardiac diagnostic procedures using currently used isotopes such as thallium-201 (where good energy resolution is required) and for first pass studies using newly developed short-lived isotopes such as tantalum-178 (where high data rates are required). We are working on a high speed signal processing technique to sustain high rates required in such applications.

Work is continuing on a device for measurement of bone loss associated with osteoporosis. If proposed funding becomes available, we hope to expand this work.

Another group, in collaboration with Professor Alexander Rich of the Biology Department, has developed an X-ray diffraction facility for protein crystallography based on a wire drift chamber detector originally developed at CERN. The instrument is now in regular use by members of the Biology and Chemistry Departments and by scholars from other institutions.

Also, LNS, through its high energy program, is partially supporting the efforts of a group who are developing cryogenic techniques of producing polarized protons for use in targets, jets, and sources. In collaboration with a group at Brookhaven, a design is being undertaken of a cold jet of nuclear polarized atomic hydrogen for use in the AGS. At MIT the production of solid nuclear polarized hydrogen is being studied.

#### Particle Theory

The "standard theories" of the interaction of quarks and leptons through gauge fields, quantum chromodynamics (QCD) for the strong interactions, the Weinberg-Salam-Glashow theory for the electromagnetic and weak interactions and general relativity for gravitational interactions are powerful and in complete agreement with experiment. But they contain no answers to the fundamental questions, why this particular hierarchy of particles and interactions? Clues can be sought within the structure of quantum field theory itself, though precedent suggests we will need further experimental input to make real progress. Since apparent new phenomena seen at the currently highest energy accelerators have proved evanescent, our efforts to correlate theoretical insights with experimental facts have been somewhat frustrated. We have continued to study a possible unorthodox dynamics of the standard theory, but must now wait for more experiments at higher energies. We have given much thought to this next generation of experiments, in particular proton-antiproton collisions in the TeV range, to see how the most useful information could be obtained.

The most radical development has been the theory of superstrings, which endeavors to unite all physics at the Planck scale, where quantum effects in gravitation start to dominate. Since this scale is quite inaccessible to experiment, we are relying on the internal consistency constraints of gauge field theory, which would make manifest the presumed deep underlying symmetries that characterize superstrings, and would make it conceivable to do nonperturbative calculations. Our continuing work on the structure of gauge field theories has been much stimulated by the boom in string theory. The richness and range of application shows no sign of diminishing.

The one place where accessible physics comes close to the Planck scale is in studies of the very early universe. We continue our work on the inflationary scenarios for the development from the big bang to the present state of the universe. Less drastic extrapolations of our particle physics knowledge have been applied to astrophysical problems such as the properties of hypothetical stars made of matter with a different quark composition from ordinary nuclear matter.

#### Nuclear Theory

An area of fundamental interest is the role of underlying quark and gluon degrees of freedom in the nucleon, in nucleon-nucleon interactions, and in nuclear structure. Although it is believed that the structure and interaction of hadrons are governed by QCD, there is as yet no quantitative theory of even the most basic questions: how do we understand the properties of a nucleon in free space, how is a nucleon altered when it is embedded inside a nucleus, and why is low-energy nuclear physics so little affected by the internal structures of nucleons? These questions are being approached both from the perspective of lattice gauge theory, and in the context of non-relativistic quark models. Studies of nuclear matter have focused on the clustering of quarks into nucleons and the experimental signature of non-nucleonic degrees of freedom. Hadron-hadron interactions have been studied in both the non-relativistic quark model and in the MIT bag model. A major new initiative has been undertaken in investigating the collisions of relativistic heavy ions, including study of the properties, evolution, and hadronization of the quark gluon plasma, understanding particle multiplicities, and seeking experimental signatures of new physical phenomena.

Nuclear many-body theory provides the foundation for many facets of nuclear theory and has therefore been an area of continuing interest. The success of relativistic models of nucleon-nucleus scattering has motivated continued efforts in the study of relativistic nuclear models and field theory. Progress has continued in the theory of nuclear collective motion, utilizing both time-dependent perturbation theory and the Born-Oppenheimer approximation.

Electromagnetic interactions have been a long-standing focus of theoretical interest in the group, both by virtue of the unique precision of the probe and the commitment to the experimental program in electron scattering at the MIT Bates Linac. A detailed study has been made of the additional nuclear structure which is revealed by studies with polarized electron beams with polarized targets and by coincidence experiments. The structure of the electromagnetic current operator in nuclei is being studied, both from the perspective of meson exchange currents and quark substructure.

#### Summary of Support

Participants in the various research programs during the past year amounted to approximately 430 people. This includes 53 academic staff members, 98 graduate students, and at least 38 undergraduates from MIT and other institutions. The latter were involved in senior theses, Undergraduate Research Opportunities Programs (UROP), work-study, and similar programs. There were 97 research staff members with Ph.D.'s, including visitors and guests, and 146 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel. At least fifteen Ph.D.'s, one M.S., and six B.S.'s were awarded based on thesis research within LNS.

Support during fiscal year 1986 from the contract with the US Department of Energy (DOE) is expected to total \$22,684,000 (after a Gramm-Rudman-Hollings reduction of \$927,000). This still represents an increase of about 7.3 percent over the preceding year. This sum breaks down as follows: operations costs (salaries, wages, materials, services, travel, and overhead) were \$13,875,000; of this \$4,581,000 was for experimental and theoretical high energy physics, \$7,771,000 was for intermediate nuclear energy physics for the support of the Bates Linac facility and research program both at Bates and elsewhere, and \$1,523,000 was for nuclear structure theory, hypernuclei, and heavy ion experiments. Equipment costs are expected to total \$8,163,000; of this, \$7,249,000 will be for high energy physics and \$914,000 for medium energy and heavy ion physics. A total of \$646,000 will be expended for accelerator improvement and general plant and construction projects associated with the Bates Linear Accelerator Center. Support for other programs within LNS, including support from other institutions and laboratories for collaborative work undertaken directly by LNS, is expected to total about \$450,000.

ARTHUR K. KERMAN

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## George R. Wallace, Jr., Astrophysical Observatory

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The George R. Wallace, Jr., Astrophysical Observatory is a teaching and research observatory located in Westford, Massachusetts. Its facilities consist of a 24-inch reflecting telescope, a 16-inch reflecting telescope, several 8- and 14-inch telescopes, a 5 1/2-inch astrograph, and a small building that houses a workshop, darkroom, and observers' quarters.

Several improvements were made to the observatory facilities. We secured the loan of two additional Celestron 14-inch telescopes, which will fill the remaining two piers in the sliding-roof building and will increase the number of students that can be accommodated from the observational astronomy courses. Dr. Edward Dunham, Mr. Richard Baron, and Ms. Alison Watts implemented several upgrades to our dual-chip CCD camera this past spring.

During the fall term, 46 students from the introductory seminar (12S23, Observing the Stars and Planets) taught by Professor Elliot, used the observatory facilities; in the spring term, Dr. Linda French taught the introductory seminar, and 71 students worked at the observatory. In the advanced laboratory course (8.287J-12.117J, Observational Techniques of Optical Astronomy), taught by Professor Elliot during the fall term, 16 students carried out independent projects at the Observatory. Several of these involved measurements of the position and structure of Comet Halley before it reached perihelion.

Mr. Michael Ressler (Class of 1986) used the 24-inch telescope to obtain some infrared photometry for his senior thesis, submitted to the Department of Physics. Mr. Ressler and Dr. Alberto Sadun published their analyses of photometric observations of the dwarf Cepheid XX Cygni. They find a total light range of 0.84 magnitudes in the V passband and 1.02 magnitudes in the B passband, which is the largest amplitude yet observed for the dwarf Cepheids.

JAMES L. ELLIOT

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## Statistics Center

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The Statistics Center (SC) was established in 1981 to provide educational and research opportunities for students and faculty interested in statistics. The academic staff of the SC is drawn mainly from Mathematics, the Sloan School of Management, and Economics. The SC is under the direction of Professor Roy E. Welsch. Next year Professor Daniel McFadden will join the Center as Co-Director. Approximately ten graduate students were enrolled in master's and doctoral degree programs. There are ten faculty affiliated with the Center, two principal research scientists, and three research scientists.

Statistical research at the SC covers a broad range of topics including estimation, classification, time-series analysis, clustering, and stochastic processes. Application of these topics included the study of nuclear reactor safeguards, earthquake aftershocks, human gait data, marketing models for detecting consumer attitude changes, and credit card thefts.

The Concurrent Computing Group under the direction of Virginia Klema is building hardware and software environments to support research on numerical algorithms and scientific applications in a concurrent computing environment. These systems are being used for high resolution spectrum estimation, signal processing, and computationally intensive statistical methods such as the bootstrap.

The Computational Statistics Laboratory, under the direction of Roy E. Welsch, is developing hardware and software systems for research on statistical strategy, statistical graphics, and expert systems for data analysis. Equipment has been provided by Xerox and IBM and more is being purchased with a DOD Instrumentation grant.

This year research at the SC has been supported by the National Science Foundation, US Army Research Office, Office of Naval Research, and the Air Force Office of Sponsored Research.

### Concurrent Computing Group

The concurrent computing group consists of Patrick Barton, Elizabeth Ducot, Virginia Klema, and Richard Kefs.

During the past year work has concentrated on building a hardware and software environment to support research on numerical algorithms and scientific applications in a concurrent computing environment. This environment consists of a number of microprocessors, all Intel components, linked together. In addition to our small manager-worker concurrent systems we have acquired a 32 node Intel hypercube for use in our research. The VAX 11/730 is a communications device and a file server for the concurrent environment. All of the Intel microprocessors have the IEEE standard for binary floating point arithmetic in hardware.

Research progress includes a software parallel tasker that permits a user to locate code and data on multiple processors, monitor communication and execution of the application, and report results to the user. Ongoing research includes the design and implementation of numerical algorithms, particularly the components of linear algebra, that are needed for scientific computation. Additional research is also underway on minimal operating systems for concurrent computing systems, and a master's thesis on this topic by Richard Kefs was completed.

Many questions arise in research on concurrent computing with respect to the level of granularity of the processing elements. Our processing elements are medium granularity but can be viewed as an interface or intermediate host to very small granularity components, say systolic arrays.

A number of algorithms for performing standard matrix computations suitable for loosely-coupled multiprocessors have been identified. Those methods will soon be implemented and evaluated on our multiprocessor architecture.

A consequence of this work has been the identification of a relatively small number of control-synchronization structures that can perform a variety of basic matrix computations. These control-synchronization structures are very high level, global constructs quite different from the language extensions that researchers have been studying for parallel computing. Ongoing research supported by NSF and AFOSR will focus on the supporting environment for debugging and monitoring concurrent computing for scientific applications.

### Computational Statistics Laboratory

This laboratory was started in 1984 to provide a place where theoretical and applied statisticians could develop new methods for data analysis that involve graphics, artificial intelligence, and intensive computing. Ongoing projects include DINDE, a data analysis environment based on Interlisp and LOOPS with provision for expert guidance; new interactive graphical diagnostics via scatterplot matrices; and simulation, for high breakdown robust methods. In addition, the laboratory is used for data analysis projects using statistical packages designed for modern graphical workstations. Teaching modules are also being developed for use on Project Athena workstations.

The laboratory is equipped with three Xerox LISP workstations, three IBM 3279 color terminals, an IBM 3277/Tektronix high resolution display, an Apple Macintosh plus, an IBM PC/XT, two SUN 2/50 workstations, a SUN 3/160 color workstation and associated servers. During the summer two SUN 3/75 stations will be installed, along with a SUN 3/160 LISP workstation and upgraded server.

In conjunction with the Concurrent Computing Group we will experiment with asynchronous concurrent computing on the SUNs when the new workstations are operational.

### Educational Programs

The Statistics Center supervised interdepartmental graduate degree programs in Statistics. During 1985-86 fifteen students were enrolled in these programs and two Ph.Ds and two MS degrees were awarded.

The weekly Statistics Center seminar series provides additional opportunities for reports on both applied and theoretical research. Speakers this year included Ben Epstein, Peter Kempthorne, and Gerald Hahn.

ROY E. WELSCH



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# Vice President in the Office of the President and Secretary of the Corporation

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## Office of the Vice President

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As of this year, the annual report on the activities of the Corporation will be included in the group of reports that follow this introductory section. At the annual meeting in October, 1985, I was elected Secretary and ex officio member of the Corporation. The new responsibilities added to the pace of work throughout the year. I am grateful to my immediate associates -- Elizabeth J. Whittaker and Nancy R. Spears in the Corporation Office, and Nancy K. Lombardi and Susan L. Kendall in the Vice President's Office -- for assuming the burden to operate both offices without a hitch.

Last year I devoted my prefatory remarks in this Report to recognizing the individual men and women on our staffs, throughout the university, who carry the daily case load of service activities, helping fellow members of the community to discharge their responsibilities and to improve their study and work opportunities. I would like to elaborate on this theme this year, with a few comments on major changes and transitions, milestones reached, and agenda set in some of the service areas for which I am responsible.

The Personnel Department has been under siege, it seems, by the extraordinary demands created by unusual turnover in the MIT support staff, and by a major reshuffle in benefits required as a result of the federal tax reform. At the time of this writing, in midsummer, there are over 150 open positions in the support staff (which totals about 1,500). Although MIT's salary structure is very competitive, and especially strong among other Boston area universities, we find that in the past year the turnover has been brisk, with several new hires occupying secretarial and other office positions for one year or less. Rapid turnover in these jobs is experienced, usually, when there is general economic prosperity as well as a shortage in personnel with office skills. We are experiencing both; and a high incidence of people who choose to do temporary work, instead of taking permanent support staff positions, compounds the problem of an unstable and increasingly expensive work force. In response to this situation, we have increased dramatically our advertising budget, and it looks as if we will have to go more heavily into formal recruiting activities and/or work with external agencies that charge fees for placement.

A formidable service agenda, and several open positions in the department's own professional staff, give the Director of Personnel an unusual management challenge for 1986-87.

In health services, the past year has been a time of major transition in the leadership of the Medical Department. Dr. Michael A. Kane, Associate Medical Director, served as Acting Medical Director and, since December 1, as Acting Department Head. A national search was launched in January to replace the Director and Department Head, Dr. Melvin H. Rodman, who decided to take early retirement, while on leave of absence. The department experienced major growth in both size and quality under the leadership of Dr. Rodman and Laurence H. Bishoff, who was the Executive Director and Acting Department Head before he resigned in November, to pursue a career opportunity outside MIT.

Much to the tribute of the department's excellence, a number of highly distinguished physicians applied for the Director's job. In June, Dr. Arnold N. Weinberg -- Professor of Medicine at Harvard University, member of the Department of Medicine at the Massachusetts General Hospital, and world-known authority on infectious diseases -- was the enthusiastic recommendation of the Advisory Committee on the search and the MIT Medical Management Board. He will take up his full-time responsibilities at MIT on November 1, and will continue his Harvard professorship and a consulting affiliation with Massachusetts General Hospital. We are very fortunate indeed to have a new Director of Dr. Weinberg's stature and reputation.

Dr. Kane, who was also a finalist in the search, withdrew his name in order to return to a more active clinical practice as an internist and expert in rheumatology. This was, of course, his own decision; and MIT will have the best of all worlds with Dr. Weinberg as Director and Dr. Kane continuing as Associate Director. I would like to add for the record, however, that Dr. Kane's short stint at the helm was nothing short of brilliant. He stepped into a complex management role with confidence and flair and led a competent team of colleagues, so that the year of transition was one of gain in every respect.

In legal services, another significant transition took place during the past year in the selection of the Boston firm of Palmer & Dodge to succeed the firm of Herrick & Smith, which had provided legal services to MIT for many decades. The lawyers at Herrick & Smith have served MIT very well; in the spring of 1985, however, we concluded that the firm had lost the breadth and depth of talent required for the many services demanded by MIT. (Indeed, a year later, the leadership at Herrick & Smith decided to dissolve the partnership.

Finding that there was no precedent, or an accepted rational approach, by which we could select one out of 10 or 12 Boston firms, all of whom were basically qualified to provide the range of services we needed, we resorted to designing our own process of informal and formal discussions, interviews, and visits, with able assistance from George H. Kidder, Esq., senior partner of Hemenway & Barnes and a well-known and highly regarded member of the legal community. It was very gratifying to see the lively interest in MIT generated among distinguished Boston firms, as well as the widespread respect that our process enjoyed in legal publications and in the local professional circles.

John A. Perkins, Esq., and Jeffrey Swope, Esq., were designated to serve as co-lead counsel from Palmer & Dodge, and the new relationship has worked extremely well. One fortuitous development was the fact that Robert E. Sullivan, Esq., who served for a long time as the partner responsible for the MIT account at Herrick & Smith, was invited and has joined the firm of Palmer & Dodge.

Still another transition occurred in the public relations area when Robert M. Byers stepped down from his managerial role as News Director to assume full-time staff writing responsibilities for the President. Bob is a veteran journalist who serves MIT with great devotion. His developing of Tech Talk as a tabloid weekly newspaper, as well as his prodigious personal energy, hard-driving style, and wry humor, set high standards of service for all of us.

Kathryn W. Lombardi, Executive Assistant to the President and Director of Campus Information Services, assumed the reporting responsibility for the News Office. There was a year-long search for a successor to Mr. Byers; and, during this period, Robert C. DiIorio was promoted to Associate Director and Mary L. Morrissey, Director of the Information Center, reached out, once again, to lend valuable assistance to Kathryn and to the News Office staff as a supervisor and wise counselor on all operating matters in the Office. In June, 1986, Kenneth D. Campbell joined us as Director of the News Office. We look to him for leadership and expanded counsel in public relations at a critical time in MIT's history.

In the Admissions Office there was also an important transition, as 1985-86 was the first full year for the new Director, Michael C. Behnke. And a remarkable year it was, with several new members added to the staff, a record number of 38 percent women admitted to the Freshman Class (10 percent more than last year), and the number of black freshmen restored to 60, its level of two years ago (last year there was a drop to 40). In addition, a new publications and marketing program was launched, and the freshman selection process was reviewed and revised in cooperation with the Faculty Committee on Undergraduate Admissions and Financial Aid (CUAFA). To my knowledge, there had been no revision of the selection process for the past 20 years.

Last spring, despite an alarming reversal in the downtrend of the past three years in the number of sophomores who plan to major in Electrical Engineering and Computer Science (EECS), CUAFA decided not to place admission restrictions for the Freshman Class that will enter in 1987, in part because this year's Freshman Class showed a relative drop in interest to major in EECS.

Our goal of greater diversity and pluralism in backgrounds and interests of MIT people is not limited to incoming students. The section of this report on Equal Opportunity, details the year's activities in this area. We made some notable strides forward in the employment of under-represented minorities -- especially blacks -- in the MIT Administrative Staff. Out of a total of about 900 on the Administrative Staff payroll, we hired, in the past two years, 30 minorities. Unfortunately, our record of hiring black and hispanic minority faculty members is not showing significant improvement and remains as our highest priority and our greatest source of frustration. The number of women faculty has increased; but, here again, the progress is slow and spotty.

Back on the student side, however, this past year we made significant headway in learning at some depth about the experience of minority students, and putting in place some plans to improve it. An extensive survey of black former students and alumni was conducted by David S. Wiley and John S. Wilson, Associates in the Analytical Studies and Planning Group (ASPG), as part of an MIT-wide study of minority student issues. The larger study was undertaken by an ad hoc Minority Student Issues Group (MSIG) consisting of 27 faculty and administrators under the leadership of Dr. Shirley M. McBay, the Dean for Student Affairs. A series of reports from the MSIG will receive widespread community attention beginning next fall. The first report in the series will be on the racial climate on campus, largely drawing on the information from the black alumni survey.

It will seem distressing to some who read this report that, at this time, and in a civilized place such as MIT, we should have to be seriously concerned with racism. Sad or painful as it may sound, it should be no surprise to anyone that racist thoughts and attitudes exist in the minds of people -- many people in our society and, yes, in our own institution. Racist behavior, however, has no place at MIT and will not be tolerated. When it does occur -- in the classroom, the dormitories, or the work place -- it must be met and be rooted out by quick and decisive action. Teachers, managers, supervisors, and all those who have responsibility for the work of other people have an additional burden to assure that racist actions are not permitted to occur within their space or their area of responsibility. They and all of

us need the help and goodwill of everyone in the MIT community to succeed in this goal. A pamphlet entitled "You can make a Difference" makes this point and reiterates our policy simply and directly. The Dean for Student Affairs has distributed this pamphlet to all incoming freshmen.

I do not know where an objective observer might rank MIT on a list of institutions -- universities or other employers -- when it comes to questions of incidence of racism or racist behavior. But I know that we can and must be the first on the list when it comes to willingness to recognize and to confront our problems, and to make the commitment necessary to improve our environment for all who study and work here.

I conclude this section of my report by recognizing, as I have in the past, the outstanding contributions of talented colleagues. Kenneth L. Hewitt, Personnel Officer, was named MIT's Black Achiever for 1986, and David S. Wiley, Senior Associate in the Analytical Studies and Planning Group, was one of MIT's two 1986 Billard Award recipients. Both men are in the midst of MIT administrative careers devoted to service. The recognition of their exceptional performance stands as a symbol for recognizing and rewarding excellence throughout the university. Exemplary service to fellow employees and to students is a special form of leadership -- strong, effective, quiet leadership -- that covers the distance between problem and solution, between need and achievement. In a large university, the quality of service provided by individual administrators can make -- does make -- the difference between a bureaucracy and a community.

Dr. Wiley leaves our area this summer to take on a well-deserved promotion as Associate Dean for Student Affairs and Head of the Undergraduate Academic Support Section of the Dean's Office. He served as an Associate in the Analytical Studies and Planning Group of our office for 14 years. We wish him the best in his new role.

CONSTANTINE B. SIMONIDES

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## Affirmative Action/Equal Opportunity

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This year has been characterized by success in recruitment of minority administrative staff and guarded optimism about future possibilities of increasing minority and women faculty members through initiatives in affirmative action/equal opportunity programs. Key developments during this period include:

1. Decentralization of the Affirmative Action Serious Search Process of the Institute;
2. Continued focus by the Equal Opportunity Staff Group to increase the minority and female presence in administrative areas; successful recruitment of more than 15 minority administrators;
3. Continuation of interaction between Assistant Equal Opportunity Officer and Boston/Cambridge minority communities at meetings and forums;
4. The strong response of the Institute to the untimely death of astronaut Ronald E. McNair.

MIT continues to move forward slowly in the Equal Opportunity/Affirmative Action area. The current work force is 13 percent minority (six percent Asian American, five percent Black American, and two percent Hispanic American) and 87 percent non-minority, 37 percent female and 63 percent male. There has been a slight change (1 percent) in the total minority population from last year.

On a positive note, the Institute hired 26 black and 4 hispanic administrators over the past two years. Our efforts to recruit women for the administrative staff maintained an upward trend, now totalling 49 percent of the staff complement of 900.

The Academic Council's decision on January 28, 1986 to decentralize the affirmative action review and approval of appointments has given senior officers direct responsibility for the progress of women and minority representation in their areas. This change in policy has already shown some positive results, noted above, in the administrative staff.

The Equal Opportunity Committee, under the chairmanship of Professor Herman Feshbach has begun to develop a strategy that holds some promise to assist academic departments in attracting minority women and faculty members. Preliminary evidence of some success in the recruitment efforts under this strategy should not give us false hopes; this has been a very difficult problem: increasing minority and women faculty at MIT remains our highest priority until substantial progress is made.

There are three other activities that should be mentioned. First a Department of Labor review in July 1986 found MIT to be in compliance with Equal Opportunity guidelines. Second, we sustained our outreach to the minority communities of greater Boston through participation in the Black Achievers Program of the Greater Boston YMCA and several presentations at meetings and conferences. Third, the tragic death of astronaut Ronald E. McNair, graduate of MIT with a Ph.D. in Physics, underscored the vast potential that exists within the minority communities throughout this country. McNair's life represents a major success model for our future recruitment efforts to provide equal opportunity to members of minority groups that are underrepresented on this campus. Through our sorrow we learned to celebrate and take pride in Ron's achievements and his inspiration to minority students across the nation. As President Gray said in his comments at the MIT memorial service on February 12, 1986, "Ron understood instinctively that he represented for a whole generation of younger people at MIT, in Harlem, and around the nation, a symbol, a shining example of what dedication, and risk taking, and hard work, and faith, and self-confidence could achieve."

In summary, the 1985-86 year has been a good one for increasing minority and female hires on the administrative staff. Serious, continuing effort during the next two years will be needed not only to increase measurably our minority and women faculty representation, but also to retain those minority and female newcomers already at MIT.

CLARENCE G. WILLIAMS

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## Office of Admissions

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In past reports to the President by The Office of Admissions, it has frequently been noted that the students who enroll at MIT are primarily the product of self-selection. During this year, we have put in motion several efforts to exert more control both by expanding the pool of applicants through improved public relations and shaping the incoming class through changes in the selection procedure.

Changes in public relations were relatively modest. We changed the way we use the Student Search Service to initiate contact with students through direct mail; we changed our published profile of the entering class to more of a report to guidance counselors so as to get their attention; we increased our travel somewhat; and we sent to all preliminary applicants a newspaper describing current events and student life at MIT. All of this was meant to communicate the breadth of the MIT experience. The results were heartening. Applications increased by eight percent to an all-time high of 6213. Applications from women increased by 15 percent, and the percentage of applicants expressing an interest in Course VI declined from 31 percent of the pool to 26 percent.

At the same time, plans were made for much more dramatic changes in public relations. Commercial firms were invited to submit proposals both for a new audio-visual presentation on MIT and for a new set of publications. Image Presentations of Boston was chosen to produce a new audio-visual presentation which will be completed by September, 1986. North Charles Street Design of Baltimore was chosen to produce a set of new publications which will be ready by Spring of 1987 to recruit the class entering in 1988.

For many years, the academic potential of applicants to MIT has been expressed through a regression formula called "The Scholastic Index". A reexamination of that index was the first assignment for Elizabeth Johnson who was hired to fill a new position, Associate Director of Admissions for Information Services and Research. Her study led us to a decision to abandon the index for selection purposes, although it will be retained for research use. With the help of The Committee on Undergraduate Admissions and Financial Aid chaired by Ken Manning, a new approach to selection was developed. After final refinements during the Summer of 1986, the new selection procedure will be put into effect in choosing the class entering in September, 1987.

The overenrollment in Course VI commanded attention again as too many freshmen expressed an interest in that department. Because of the progress made in attracting fewer potential Course VI students in the Class of 1990, CUAFA decided to not impose a restriction on enrollment in Course VI. Instead the faculty gave CUAFA a two year extension of their authority to impose such a restriction. They also directed the admissions staff to investigate the possibility of making admissions decisions with some sensitivity to applicants' likely choice of major. The staff will conduct that study during the summer and fall of 1986.

The enrollment of black students recovered after a decline last year, to a normal level for recent years. Dissatisfaction with that "normal" level led to several steps. One was the addition of another professional to concentrate on minority student recruiting. Eduardo Grado was appointed to the position. Unfortunately, Nels Armstrong, the Associate Director in charge of minority student recruiting, resigned, and we were unable to replace him. We are still trying to find someone to work with Mr. Grado. Another step to strengthen minority recruiting was the development of a program called Pathway to the Future. This includes one new initiative - a new person in The Office of Career Planning and Placement to help place minority students in rewarding summer jobs. Other parts of the program already existed but had never been brought together in a form which can be advertised to prospective students.

The biggest challenge for the Office this year was to learn how to function without Julia McLellan, who retired at the end of the summer. Fortunately, with her great personal force and administrative ability, she left behind a superb staff and smoothly functioning process. We are confident that these changes and others to come will result in many positive outcomes.

MICHAEL C. BEHNKE

ADMISSIONS TRENDS 1977 - 86

	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>
<u>Entrants from Secondary Schools</u>										
Preliminary applications	7,853	9,320	10,274	11,223	12,526	12,525	12,653	12,465	14,698	14,349
Final applications	4,838	4,870	5,368	5,677	5,922	5,921	5,959	6,055	5,743	6,213
Admissions offered	1,939	1,865	1,813	1,809	1,909	1,898	1,817	1,854	1,885	1,764
Actual registration	1,073	1,059	1,059	1,081	1,031	1,050	1,109	1,059	1,061	1,001
Registrations as percent of admissions	55.3%	56.7%	58.4%	59.7%	54.0%	55.3%	61.1%	57.1%	56.0%	57.0%
Number of secondary schools represented	859	877	893	894	835	842	891	722	865	830
Percent of students from 9 northeastern states	52.0%	50.6%	49.0%	47.8%	51.9%	51.0%	50.5%	50.5%	44.5%	43.5%
<u>College Transfers</u>										
Total Applications	1,079	1,074	1,143	1,131	818	1,378	1,024	1,048	850	890
Applications completed	591	535	486	471	399	425	400	304	340	317
Admissions offered	175	172	152	167	93	118	128	124	129	137
Actual registrations	141	123	124	119	76	82	91	91	86	107**
Registrations as percent of admissions	81%	72%	82%	71%	82%	69%	71%	73%	67%	78%
<u>Graduate Students</u>										
Total Applications	7,740	7,454	7,849	7,832	9,075	9,342	8,836	7,922	8,157	8,564
Admissions offered	2,644	2,724	2,636	2,380	2,926	2,920	3,007	2,223	2,612	2,457
Actual registrations	1,369	1,461	1,362	1,212	1,465	1,476	1,542	1,290	1,197	1,196*
Registrations as percent of admissions	52%	54%	52%	51%	50%	51%	51%	58%	46%	49%

\*Planning to register as of 7/15/86; an additional 624 have not yet notified MIT as to their intentions.

\*\*As of 7/15; may be fewer by September.

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## Educational Council

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Alumni/ae totaling 1,558 served as Educational Counselors this past year, representing MIT in all 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, and 43 foreign countries. This group included 244 women and 65 minorities (48 Blacks, 7 Puerto Ricans, and 10 Mexican-Americans). The Educational Counselors represented MIT at 200 local College Fair programs, they conducted 6,465 admissions interviews, and held countless conversations with prospective MIT students and with local school personnel. A record number of 96.1 percent (98.4 percent within the United States) of all applicants were interviewed by a local Educational Counselor.

Project Contact is a program which puts current undergraduates in touch with applicants, Educational Counselors, and school personnel. This past year 397 students, representing approximately 82 different geographic areas (including 15 foreign countries), participated in this program run by the Educational Council Office.

Meetings for newly admitted students were held in 32 cities throughout the United States by Educational Council groups. Nineteen of these meetings were held during MIT's Spring Break and panels of current students were at each of these meetings.

MIT Open House Meetings were held throughout the United States in the fall. Local Educational Council members assisted members of the Admissions staff in arranging for 113 Central Meetings in 98 cities.

The Educational Council continued to provide support to coordinate the AMITA High School Visiting Program. This year 150 volunteers made visits to 49 high schools in the Greater Boston Metropolitan Area.

BONNY S. KELLERMANN

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## Department of Athletics

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During this sixth year of my tenure as Director of Athletics we have made every effort to sustain and even expand one of the most highly participative and broadest based programs in the nation while undergoing difficult but necessary changes to prepare for Department and MIT needs in the 1990's and beyond. These changes are in process and intended to enhance career satisfaction and improve effectiveness of our dedicated complement of teachers, coaches, administrators and support personnel:

### Tenure in Athletics

Frequently reminded of the sharp differences in tenure review criteria and process in comparison to our academic departments we have been encouraged by senior administration to review our tenure system for "athletic faculty." We agree with the need to review and are working closely with the MIT Professors on the Athletic Board to seek an appropriate non-tenure system that supports our commitment to education and the opportunity for stable career development while overcoming the serious inequities currently existing with a rather arbitrary tenure or non-tenure dual track system.

### Teaching Evaluations in Physical Education

The first comprehensive and objective evaluation procedure for all Physical Education instructional staff was initiated during the second semester. Student evaluations and regular reviews with follow-up by a senior department committee are the nucleus of this on-going system designed to improve professional knowledge and performance. The procedure will be expanded in the coming year to embrace all part-time instructors.

### Reorganization of Senior Department Management

Concurrent with the final year of retiring Assistant Director, Jack Barry, we have initiated a series of organizational shifts and promotions effective July 1, 1986 to be firmly operational by February 1, 1987. We believe these changes reflect our philosophy of professional career development, our commitment to minority recruitment and our preparation for future departmental leadership.

### Restructuring Physical Plant/Athletic Department Utility Workforce Balance

In order to gain greater flexibility in program support and improved efficiency in workforce scheduling, we have begun to examine the various supervisory, labor force and union arrangements of our various disconnected work units, i.e., Athletic Utility Unionized Personnel; Equipment Desk Support Staff; Alumni Pool Lifeguards; Pierce Boathouse Attendant and Rigger; Physical Plant Unionized Grounds Staff.

We are planning a feasibility study in conjunction with Physical Plant and Personnel to determine (a) if the Athletic Department should be employing and supervising outdoor facility maintenance personnel as well as indoor and (b) possible options for combining some or all of our currently disconnected work groups to allow much needed job interchangeability, assignment flexibility and worker job variety/versatility.

In addition to these four important initiatives we continue to focus particular effort on the following high priority areas:

- Physical Education revisions, updating and clarification in mission, program emphasis, curriculum and student requirements.
- Facility improvement and new development, particularly the redress of numerous inequities in locker-room space for women; the refurbishment or replacement of deteriorating structures such as Alumni Pool, Rockwell Cage and Carr Tennis Bubble; the upgrading of and gradual transition to state-of-the-art synthetic all-weather outdoor field surfaces.
- The continuing spread of health fitness/wellness understanding and education for the behavior and life practice of the MIT Community. This effort will be in close collaboration with the Medical Department for the benefit of all students and MIT personnel.



- Improved selection processes and training methods for the Intramural cornerstones of student management and contest referees.
- Development of new and improved administrative and information systems for the planning, communication and follow-up with internal constituencies particularly coach and administrative leaders responsible for intercollegiate programs, logistics and uniform/equipment needs. This effort involves the development of a sophisticated and workable electronic business operation to be fueled by (a) participation in the Administrative Information Systems Strategic Plan with Jim Bruce and (b) through close collaboration with Steve Scarano, the new Assistant to Vice President Simonides for Information Systems.
- Strengthen the Department's commitment and organizational response and follow through for the increasing variety and number of local community and state wide special events held in our facilities and hosted jointly with the MIT Office of Special Events and other departments of the Institute. This outreach activity is viewed as an important component of the gradually improving image of MIT as an enlightened and positive force in society.
- Recognize the MIT Athletic Program as an excellent source of strength and public relations for MIT and continue to develop ways to capitalize on this resource for the benefit of MIT, the future student applicant pools and the forthcoming Capital Campaign. This is particularly important in light of the recently launched search for a new Sports Information Director to replace Ken Cerino, our talented and effective colleague and friend who leaves to seek broader opportunities at Springfield College.

Satisfactory conclusions with most or all of these on-going initiatives should keep our Department in a strong position as a vital and effective respondent to the Institute's ever increasing and shifting opportunities and demands for our services in the years ahead.

Included with this report are three exhibits providing key participation statistics (Exhibit I) and October, 1985 Long Term and Current Year Departmental Priorities (Exhibits II and III).

A separate concise statistical review of our wide ranging activities has been compiled in 14 exhibits and submitted for forwarding to the Institute Archives. A brief summary of the Archive exhibits follow:

#### Intercollegiate Athletics

MIT men's and women's intercollegiate varsity teams enjoyed another successful competitive year in 1985-86 posting an overall record of 299 wins, 232 losses and four ties for a combined .563 winning percentage. Of the 22 men's teams recording won-loss records (out of 24 - no records can be appropriately compiled for sailing and skiing) 14 squads had winning marks with an overall .566 winning percentage. The women's intercollegiate program had five winning seasons out of 11 programs (again sailing not included) with a fine .557 winning percentage.

Women's Soccer and Men's Volleyball each completed its first season of varsity intercollegiate competition on a solid positive note. In the fall the women's soccer team, under the direction of first year part-time coach Shawn Ladda, enjoyed a highly competitive 6 win 7 loss record beating Wellesley 1-0 in its very first game at the Seven Sisters Tournament held at Mt. Holyoke. They also won their first home game 3-2 over Salem State.

The MIT Men's Volleyball Team, after losing their first match 3-2 to Dartmouth at Hanover, proceeded to win their next seven consecutive matches en route to a fine 25-10 record. Coach Karyn Altman's team won the Northeast Conference Championship of the Eastern Intercollegiate Volleyball Association and the New England College Volleyball League. In the final national poll MIT was ranked 20th, tied with Princeton.

In November, MIT men's and women's basketball teams participated in the first Coed Classic hosted by the University of Chicago with Rochester and Washington University of St. Louis. MIT will host the same tournament in November, 1986, in honor of former basketball standout and currently major financial supporter David Koch, '62.

#### Physical Education

Under Professor Gordon Kelly's effective third year directorship, there have been several important accomplishments this year including (a) implementation of a staff evaluation procedure, (b) installation of an IBM-AT on-line computer system for entry, monitoring and reporting of student registration data, (c) completed full training of newly hired secretary Kristine Sullivan, (d) expansion of the increasingly popular summer course and IAP offerings including more opportunity for student credit, and (e) initiated discussions with CAP to smooth further the delinquent "senior crises" through the establishment of a legitimate two-year (freshman/sophomore) physical education completion requirement.

There were 55 courses offered by Physical Education in 1985-86 with total registrations slightly below the record levels of last year but still well above the average of the last five years. Our full-time staff is back to full strength (19) with the positive additions of Karyn Altman and Bruce Beall. Twenty-three part-time instructors supplemented our full-time staff including superb contributions by Stephan Driscoll in our versatile dance program and Niece Manello in our extremely popular (up to 50 people daily) noon-time exercise fitness classes. A new aerobic dance fitness program was offered in the early evening and proved to be quite popular.

We are pleased with the new swim test procedures implemented two years ago. The new procedures for combining the swimming and boating tests as well as the new certificates and filing system have improved efficiency and increased early season student completions. Our goal is to get 90% of the freshmen swim testing completed in early September with follow-up to get the final 10% sometime during the freshmen year. A request has been made through the CAP to attach a late fee to any necessary tests that must be completed after the established testing dates.

Our expanding PE Summer Program includes seven activities for credit (expanded to eight in 1986-87 with the addition of tennis). Exercise fitness and aerobic dance continue to be very popular. Masters swimming is also growing in popularity with both sessions filled to capacity of 30. Sculling is an area with exceptional potential for future summer group programs.

#### Intramurals

Under the direction of Professors David Michael and Jean Heiney two interesting initiatives have begun in 1985-86: (a) establishment of an IM Referee Club as an administrative and social vehicle for the organization, motivation and training of student IM referees and (b) creation of a jointly sponsored triathlon event with the MIT-Wellesley Exchange Program. The event is scheduled for September 27, 1986 to be comprised of a half mile swim, ten mile bike ride and four mile run.

IM participation continued strong and healthy in 1985-86. In 1986-87 we expect a banner year with the new referee club, a revised clerical support structure, increased emphasis on use of electronic information systems and more creative use of administrative support people and communication systems.

#### Club Sports

The Club Program under Professor Jack Barry's leadership continues to prosper. During the past year two new clubs were added - Women's Graduate Crew and the Master's Swim Club. Both programs are consistent with our on-going commitment toward the growing graduate population. Two of last year's active club programs - Women's Soccer and Men's Volleyball moved successfully to intercollegiate status after years of important support at the club level. In 1985-86 the combined participation of undergraduates and graduate students was 1,052, an all-time record level.

#### Athletic Operations and Facilities

The past academic year 1985-86 marks the final full year of Professor Jane Betts' strong leadership as Assistant Director for Operations and Facilities.

#### Major Project Highlights

- Area A Synthetic All-Weather Field - Developed project to issuance of bid requests on July 7, 1986. Expected completion date is mid-fall, 1986.
- Rockwell Cage Curtain System - Installed in late spring, 1986, a two tier opaque ultraviolet resistant curtain system on all four sides of Rockwell Cage. The appearance of Rockwell Cage is enhanced considerably with the added benefits of heat loss reduction and control of outside sunlight distraction.
- Area B Field Area - Completely renovated with natural turf providing a dramatic improvement in safety and playability for all field sports.

The highest priority projects for 1986-87 in addition to the completion of the Area A Synthetic Field include (a) Alumni Pool reconditioning and improved accommodations for women, (b) reorganization of existing space in Pierce Boathouse to improve exercise area and increase locker room space for women, and (c) completion of the reshaped "Dance Studio" on the third floor of the Armory as the final step in the space sharing project with Campus Police.

During 1986-87 Assistant Director Rod Arthur will assume responsibilities for the Operations function. He and Jane Betts will take the lead jointly to discuss and study the feasibility of combining Physical Plant outdoor facility personnel and our own indoor Athletic Utility personnel under Athletic Department supervision with multiple indoor-outdoor assignment options.

### Sports Publicity and Communications

Ken Cerino's final year as Director was filled with several outstanding accomplishments. One particularly impressive and valuable effort was the hometown release project where 65 stories on students, coaches and staff were distributed to newspapers across the nation.

Several feature articles resulted including:

- A color spread on three-sport star Grace Saccardo, '86 in the Attleboro, MA Sun Chronicle.
- A feature on two-sport star Craig Poole, '86 in the Eastern Shore, VA News.
- A profile of women sailing captain Louise Sedlacek in both the Boston Globe and Hinsdale, IL Doings.
- Sports Medicine Coordinator Paul Grace featured in the Essex County, MA newspapers.
- A profile on part-time Women's Soccer Coach Shawn Ladda in the Framingham, MA Middlesex News.
- A Boston Herald feature on MIT's National Championship Pistol Team and football captain Larry Monroe.

The Sports Publicity Office also assisted in the organization of two major track championships and several special events held at MIT during the year.

### Sports Medicine and Health Fitness

This has been a productive and satisfying year for Coordinator Paul Grace and his dedicated staff - Kathy Davis, Gary Rizza, Del Smith and the Northeastern Student Interns. There were over 3,000 different athletic related injuries treated by the sports medicine staff with over 4,000 cumulative treatments administered through the co-educational sports medicine facility in duPont. Orthopedic evaluation was provided to 321 students and we received 104 patient referrals from the Medical Department.

In 1985-86 athletic training services were expanded to include the new intercollegiate sports of women's soccer and men's volleyball plus the competitive and physical club sports of men's and women's rugby, women's lacrosse and women's track. Sports Medicine also increased their services and availability to the various crew programs.

Important accomplishments include:

- Introduction of an Institute-wide individual fitness assessment program. Over 100 members of the MIT Community were tested for fitness level with recommendations for improved condition. We also offered separately six sessions of body fat assessment and low back flexibility.
- Addition of a formal exercise component to the Sloan Senior Executive Fitness Assessment Program. This program and the one planned for the Sloan Fellows this summer are both coordinated by staff athletic trainer, Gary Rizza.
- Upgrading of data management has improved information flow to coaches on student injury status.
- Initiation of a Sports Nutrition Seminar for all segments of the MIT Community but particularly athletes.

The Class of 1974 IM Health Fitness Center under the direction of Paul Grace/Sports Medicine has added three aerobic exercise bicycles and a variety of free weight equipment while attracting 6,000 cumulative users per month during the 1985-86 academic year. Two satellite centers were developed at Alumni Pool and Pierce Boathouse for geographic convenience and a partial relief to the Class of 1974 Center. These satellites will have selected equipment additions in 1986-87.

The MIT Department of Athletics marches through this important transition phase fortunate to have people of outstanding personal qualities and strong commitment to the philosophy of Division III Amateur Athletics. We are pledged to preserve the special mission of athletics in the MIT environment and to continue change whenever appropriate in the preparation of MIT Athletics for the new century.

ROYCE N. FLIPPIN, JR.

## EXHIBIT I

## MIT ATHLETIC PROGRAM PARTICIPATION

	Report Year 1985-86	1984-85	1983-84
STUDENT ENROLLMENT (October Figures - Includes Specials)			
Undergrad Women	1,165	1,157	1,090
Undergrad Men	<u>3,376</u>	<u>3,379</u>	<u>3,512</u>
TOTAL	4,541	4,536	4,602
Graduate Women	1,042	1,054	976
Graduate Men	<u>4,204</u>	<u>4,036</u>	<u>3,999</u>
TOTAL	<u>5,246</u>	<u>5,090</u>	<u>4,975</u>
GRAND TOTAL STUDENTS	9,787	9,626	9,577
STUDENT PARTICIPATIONS (Includes Multiple Activity Duplication)			
1. <u>PHYSICAL EDUCATION</u>			
Total Registrations	<u>6,512</u>	<u>6,589</u>	<u>6,401</u>
(Undergrad)	(5,324)	(5,298)	(5,149)
(Grad)	(957)	(909)	(848)
(Staff)	(231)	(382)	(404)
2. <u>INTRAMURALS</u> (M/W & COED)			
Programs	21	24	25
Teams	1,077	1,180	1,180
Students	10,846	11,779	10,845
3. <u>CLUBS</u>			
Programs	35	35	32
Students	1,052	985	857
4. <u>INTERCOLLEGIATES</u>			
Women's Programs	<u>12<sup>(1)</sup></u>	<u>11</u>	<u>11</u>
- Student Participants	211	205	206
- Varsity Letter Awards	142	112	111
Men's Programs	<u>24<sup>(2)</sup></u>	<u>23</u>	<u>23</u>
- Student Participants	582	604	596
- Varsity Letter Awards	330	321	267
(1) Addition of Women's Soccer			
(2) Addition of Men's Volleyball			

EXHIBIT II

October 1985

MIT DEPARTMENT OF ATHLETICS  
FIVE-YEAR LONG-TERM STRATEGIC OBJECTIVES

FUNDAMENTAL MISSION

- To provide a high quality student-oriented physical education, recreation and athletic program that emphasizes participation and adapts to important trends. To enhance the MIT human environment for the entire MIT Community.

LONG-RANGE (FIVE-YEAR) OBJECTIVES

- Hire high quality people. Develop their professional skills and personal/career growth. Improve minority faculty/staff representation.
- Continue to carefully manage and selectively expand one of the largest percent participation programs in the United States in intramurals, club offerings, intercollegiate teams and general recreation opportunities; emphasize continued growth of women's athletics.
- Stress the relevance and quality of physical education programs in the MIT educational context and the student community.
- Support and develop technology-aided health fitness; gradually expand campus-wide health fitness education and testing programs.
- Develop external resources for improvement of existing facilities. Plan and promote implementation of Phase III new facilities, artificial field surfaces and planned renovations.
- Gradually consolidate responsibility for all outside maintenance and building services associated with athletic programs.
- Reorganize office space and work locations for improved efficiency and cooperation within the Department.

EXHIBIT III

October 1985

MIT DEPARTMENT OF ATHLETICS

CURRENT PROGRAM PRIORITIES

1. Introduce new communications and planning systems to improve operating efficiencies and reduce pressures on coaches and supporting work force; consolidate 36 sport intercollegiate program.
2. Structure future leadership organization effective 1986-1991.
3. Hire minority faculty/staff.
4. Manage existing facilities and new projects on a cost-efficient priority basis; install Area A artificial surface.
5. Improve quality and relevance on Physical Education course offerings; support the P/E leadership in professional staff training and staff evaluations; reexamine philosophy and practice of non-course credit.
6. Implement campus-wide health fitness testing program.
7. Transfer Physical Plant field maintenance personnel to Athletic Department.
8. Consolidate gains in graduate student participation in club and intramural programs; increase club sport budget.
9. Improve communication with MIT student body.
10. Develop close supportive relationship with Admissions Office to enhance quality of MIT matriculants.

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## Campus Information Services

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This year, the Campus Information Services were expanded by the addition of the News Office, thus bringing into one organization the responsibilities for central Institute communications with the general public. The offices within the area now include the Communications Office, the Office of Design Services, the Information Center, and the News Office.

Highlights of the past year included the assessment and revision of MIT's news policy in the course of the search for the new Director of the News Office. This assessment led to an institutional commitment to a more active posture vis a vis the news media, in order to heighten MIT's profile nationally and to portray a more accurate picture of the Institute. The News Office has already begun and will continue to develop media plans in support of major institutional objectives such as the reform of undergraduate education, the recruitment of a more intellectually and socially diverse group of students, and the upcoming fundraising campaign. In June, Kenneth D. Campbell joined MIT as Director of the News Office, succeeding Robert M. Byers who had served in that position for 14 years, prior to his assuming responsibilities as senior writer for the president and other senior officers. Mr. Byers' talents as an expositor of complicated issues, together with his encyclopedic knowledge of MIT, set standards that are hard to match. We look forward to Mr. Campbell's building on the accomplishments and strengths of the News Office.

The year also brought a flurry of major institutional events, including the dedication in October of the Jerome and Laya Wiesner Building, housing the Media Laboratory, the Council for the Arts, and the Albert and Vera List Visual Arts Center. The building and its programs are fitting tribute to the Wiesner's dedication to MIT and to their sustained advocacy of the arts and communications technologies. In December, the Institute dedicated the wholly renovated "Building 39" in honor of Gordon S. Brown, former Dean of Engineering at MIT, a pioneer in engineering education, and an early advocate of interdisciplinary research enterprises. The Brown Building now provides the principal campus focus of MIT's burgeoning program of research and teaching in the fast-moving field of micro-electronics. In April, the MIT community celebrated the 125th anniversary of the Institute's founding with a symposium on the world economy, sponsored by the Sustaining Fellows of MIT, and with a gala Quasiquicentennial Ball for faculty, students, staff, and alumni. While scores of people joined forces to create these events, special credit goes to Mary L. Morrissey, Director of the Information Center, for her steady hand and guiding spirit throughout the planning and execution of these programs.

Another major set of activities this year was our participation in Admissions' programs. These activities included the development and ongoing implementation by the News Office of a media plan in support of Admissions goals, logistical support for "Campus Preview" visits by admitted students, preparation of information for prospective students, and participation in the case for and selection of a marketing firm to prepare recruiting materials.

In the year to come, the Campus Information Services will be much involved in the Campaign for MIT, particularly in creating a higher national profile of MIT via the news media, and in assisting with communications and events to support this major fundraising drive to increase the endowment. In addition, we will continue to work on the image of MIT and the communications from MIT, so that high school students with a diversity of backgrounds and interests see MIT as a place for them.

KATHRYN W. LOMBARDI

### COMMUNICATIONS OFFICE

This year the Communications Office completed several special publishing projects in addition to the production of its annual publications and consulting responsibilities within MIT.

In the fall, the 1985 revision of Policies and Procedures was printed and distributed to faculty and staff. The new edition incorporates major changes in policies covering such matters as privacy, open research, harassment, retirement, the research staff, the annual salary plan for faculty, and vacation and other benefits. The Communications Office provided editorial and production assistance on the project, which was managed by John M. Wynne, Vice President, Emeritus.

A new project we undertook this year was the research and writing of 33 single-sheet descriptions of the academic fields at MIT that are open to undergraduates as major courses of study, as electives, or as special interests. The sheets are available as handouts to prospective students at college nights and in the Admissions Office. In addition, the descriptions are being mailed to prospective undergraduates who write to MIT for information on particular areas of study. The copy was word processed onto a letterhead with seven small photographs and the slogan "MIT -- A Place to Explore." The project was very modest in terms of dollars, but we think it was an important first step in providing information that is targeted to an individual student's interests.

Another special project in 1985-86 was editorial and production assistance of the bound summary Long-Range Plan for MIT. The Plan had been coordinated by the Institute Planning Group, chaired by Francis E. Low, Provost from 1980-85.

During the summer and early fall, the Communications Office was involved in an Institute-wide photo contest, sponsored by the Admissions Office. Participants submitted black and white photos of MIT people and scenes in six categories. Cash prizes were awarded to the three best entries overall, and the three winners of each category received autographed copies of Moments of Vision by James R. Killian, Jr. and Harold E. Edgerton. Photos submitted for the contest are the property of the Institute and can be used in MIT publications as long as credit is given to the photographer. The contest helped us to identify some fine student and staff photographers within our midst, and provided us with some new views of MIT and its people.

The President's annual statement was changed this year to include short profiles of six junior faculty members. The profiles helped to personify some of the themes in the report such as the needs for career development support of faculty and for more endowed research funds. Initial research for the profiles was provided by this Office and by the Communications Office of Resource Development.

Starting this year, the Office took advantage of word processing and personal computer systems within the Institute to help produce two of its annual publications. Manuscript copy to the 1986 edition of the Summer Session Catalogue was updated, coded for type font changes, and telecommunicated via phone lines to a local typesetter, all done through the office's DECmate III word processing system. The task of updating tear sheets from last year's catalogue was completely eliminated, and overall production time was reduced.

Typesetting production on Chapter 8 (listing of subject descriptions) of the 1986-87 Courses and Degree Programs catalogue also was handled differently. All subject information was updated as usual by personnel in the catalogue division of the Registrar's Office, but this year was directly input onto floppy disks with the appropriate typesetting codes included. The Registrar's Office used an IBM PC system. This resulted in a much faster turnaround time of galley proofs from the typesetter and lower typesetting charges. During the next year, the Communications Office plans to purchase a similar IBM system, so that more of the book can be updated in this manner.

There will be a new look to the next edition of the Student Telephone Directory (1986-87 version). On an experimental basis, the book will contain a section of "yellow page" advertisements and listings. The Office has contracted with a company specializing in university directories that will handle all phases of the production process. They will sell ad space to local merchants, typeset the student name and number copy, supply paper, print a four-color cover, and print and bind the books. (In the past, the student section was produced from computer-generated printouts and was difficult to read.) All production costs of the new Directory will be paid for by money generated from the advertising, and MIT will further benefit by a revenue sharing plan with the directory company. We hope that these changes to the Directory will make it a more useful and attractive document.

There were several personnel changes in the Office this year. In August, Nancy Ferrari joined us as Administrative Staff Assistant. Previously she had worked at the Journal of Science, Technology, & Human Values and at the Center for Space Research, both at MIT. Carolyn Magnuson, a Simmons College student who had provided invaluable assistance to us for three years, left in April to work for a public relations firm. In March, Janet Snover, Communications Manager since 1981, moved to a new position at MIT's Graphic Arts and Audio-Visual Services. She will serve as Manager of Customer Relations and Services, providing liaison between the Institute's printing and typesetting shop and the community. Mark Wilson, Production Manager of the Office since 1981, has been promoted to Communications Manager.

JANET SNOVER  
MARK WILSON



## DESIGN SERVICES

The Office of Design Services continues to support the communications efforts of MIT by designing and managing the production of publications for departments and offices throughout the Institute. Among the areas receiving major assistance from the office during the past year were the Corporation, Committee on the Visual Arts, Resource Development, the School of Engineering, the Sloan School of Management, the Special Summer Programs, and a wide range of special events and conferences coordinated by the Information Center. Included among these were the dedications of the Wiesner Building and the Gordon Stanley Brown Building, and the celebration of MIT's 125th Anniversary.

Overall the office undertook 274 graphic design and publishing projects in 1985-1986.

In 1985 Ralph Coburn gave a lecture on his painting at the Montserrat College of Art. His paintings are exhibited at Southeastern Massachusetts University. Celia Metcalf received a Merit Award from the Art Directors Club of Boston.

Jacqueline Casey was invited to serve on the Yale University Visiting Council for the Art School. She was also a guest lecturer there. Her work was included in several exhibitions: Images for Survival: Peace Posters in Hiroshima, Nagasaki, Nagoya, Osaka, and Tokyo, Japan, Cooper Union in New York, and the Massachusetts College of Art in Boston. Her work was shown at the Lahti Poster Biennale in Finland and is part of the Type Directors Show in New York. Her posters are in the collections of the Staatliches Museum Fur Angewandte Kunst in Munich, Germany. Among the past years publications in which her work appears are Graphis, Switzerland, 1985, "Typography 6," Watson-Guption Publications, 1985, Japanese Peace Posters, Dai-Nippon Printing Company, 1985, and "Posters by Members of the Alliance Graphique Internationale 1960-1985," Rizzoli International Publications, 1986.

JACQUELINE S. CASEY

## INFORMATION CENTER

Entering into the Institute's quasiquicentennial year, the Information Center continued to serve as a major public relations arm of MIT -- providing services and information in print, in person, and over the telephone to Institute visitors and staff and coordinating a record number of Institute celebrations, dedications, meetings, and conferences.

Public Relations and Information Services. Although there are many stresses and demands on the Center and the many offices they deal with, we were able to adjust to the many budget restrictions and changes that are constantly happening.

During the past year, the Center continued to be a clearinghouse for over 11,000 pieces of mail addressed to MIT; maintained the official Institute mailing lists of over 3,000 individuals; answered and directed to other offices over 30,000 telephone and over 35,000 office inquiries from the public and the MIT community; distributed over 42,500 pamphlets, brochures, guides, and catalogues; maintained the five-year planning calendar; maintained records, prepared reports, and published a Tech Talk supplement describing over 60 faculty and presidential committees. Over 7,000 visitors took guided tours conducted by 20 of our student staff. The tour guide captain, Ellen Epstein, '86, worked full time during the summer, the busiest time for visitors. She was assisted by David Kramer, '88. Arrangements were made for 30 delegates and 3 greetings for other universities' inaugural ceremonies.

Special Events and Conferences. In March, the Special Events Office was renamed the Conference Services Office and its head, Gayle M. Fitzgerald, was promoted to Manager of Conference Services. This office managed the logistical arrangements of fifteen conferences which brought over 6,500 people to campus. In addition, the office coordinated the logistics for the Massachusetts Special Olympics, held in June, that brought over 3,000 people, including 1,500 athletes, to campus.

In addition to conference coordination, this office assisted with the management of the Admissions Office Campus Preview and the Minority Spring Weekend in April, assisted the Institute Colloquium Committee with their first year's three programs, and handled the arrangements for over 90 on-campus recruitment presentations in conjunction with the Office of Career Services and Preprofessional Advising.

In July, Sarah Clere left MIT to pursue a career in computer software; her spirit and dedication will always be appreciated. We welcomed Elsie Bennett Kappler as Senior Secretary in October. I am

grateful to Charles Peckham, '85, and Felicia Duran, '85, for their tireless efforts with many summer and fall conferences.

The director had a very busy year coordinating building dedications, the Quasquicentennial Ball, and Commencement. The Quasquicentennial Ball, celebrating MIT's 125th birthday, was a happy and festive occasion with over 1,500 people dancing to Dick Johnson's Swing Shift and the Intermission Trio Plus, led by Associate Provost Samuel Jay Keyser.

As most know, Commencement this year had some firsts. We distributed diplomas simultaneously for the Bachelor of Science degrees and for advanced degrees. President Gray presented the Bachelor of Science degrees, and Provost Deutch presented the advanced degrees. Prior to the Exercises, Dean Perkins hooded the doctoral degree recipients. Also for the first time, Commencement went on despite a continuing drenching rain. The Exercises were not held in our back-up for several reasons, including continued reports that the rain would stop, and the delay necessary to resort and set up diploma distribution in the Athletics Center. Mistakes were made and other arrangements will be considered for preparation in the event we ever have another storm similar to the one on 2 June. Two thousand twenty-seven degrees were distributed to 1,946 students.

International Visitors Office. The year 1985-86 was an interesting and busy one in the International Visitors Office. There were more people to serve, new projects, plans and immigration issues to confront, conferences and workshops to attend as well as to plan and present, opportunities for professional development and continued involvement with the Committee on International Institutional Commitments.

Foreign faculty and staff grew, continuing a trend of many years. This year's international community totaled 1,452, a 12.5 percent increase over 1984-85.

The Immigration and Naturalization Service published memoranda in the fall which described the concept of "dual intent" -- allowing that those who may wish to stay permanently in the United States may still be eligible to extend a temporary visa. While it was unsure at times if the idea would prove as beneficial as it sounded, it has enabled several individuals to stay legally on temporary visas while the slow process of applying for a "green card" with Institute support wound on. Whether the Immigration Service will continue to acknowledge two kinds of intent is uncertain.

The addition of a word processor made it possible to quickly update the list of foreign faculty and staff, as well as to easily access and update a whole range of instructions, booklets, information sheets, and standardized letters.

Virginia Lyons and Dora Waldin announced their impending motherhood. Ms. Lyons took a four-month maternity leave, and Ms. Waldin chose not to return to work. The expected absence of two of the International Visitors Office staff required advanced planning to continue the smooth operation of the office. Ms. Mary Clark, former Associate Director of the Bechtel International Center at Stanford University was hired to replace Ms. Lyons temporarily and Ms. Virginia Silverman, former administrative assistant in the International Visitor's Office, was rehired on a part-time basis for the summer, sharing Ms. Waldin's position with Ms. Martha Lyman, '88.

The office continued to provide information to others at MIT about the often confusing immigration procedures and policies by offering two workshops, in the fall and spring, geared to MIT administrative staff. The workshops are under the auspices of the Personnel Development program. Ms. Lyons and Lillian Whelpley were the presenters. Between 40 and 50 people attended.

Terri Priest ably and efficiently handled 592 short-term sponsored foreign visitors.

Ms. Whelpley became involved with the J-1 exchange visitor visa program as an alternate responsible officer in addition to continuing to work with the H-1 visa and sponsored visitors such as Fulbright and IREX.

Ms. Lyons participated in a NAFSA sponsored effort to write a paper on working with foreign scholars, aimed at the universities and colleges that are only recently hiring and hosting foreign faculty members, research staff, and visitors. Begun during a three-day meeting in July 1985 at Cornell University with a small group from UC Berkeley and Davis, the University of North Carolina at Chapel Hill, the Council for International Exchange of Scholars, the Virginia Polytechnic Institute and an immigration lawyer, it led to the publication in May 1986 of a working paper, A Concern for Quality: The Foreign Scholar's Experience in the United States.

The Committee on International Institutional Commitments continued to review a large number of proposals, providing advice to the administration, faculty, and staff. A report on the Committee's activities was prepared and presented to the faculty at its March meeting. During Ms. Lyons'

maternity leave, Ms. Charlene Placido of the School of Science kindly agreed to fill her role, reviewing materials submitted, setting the agenda, conferring with the chairman, Professor Eugene Covert, and scheduling meetings.

The end of this academic year marks the retirement of Dean Eugene Chamberlain, International Students' Advisor and long-time friend, colleague and supporter of the International Visitors Office. Gene has been a concerned advocate of international students and the quality of life for all of MIT's international community for over 30 years. He will be greatly missed by all of us.

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The Center accomplishments and goals depend on the teamwork of everyone in the office. A special tribute is due to all the staff -- Virginia Lyons, Gayle Fitzgerald, Lillian Whelpley, Kathleen Barrett, Terri Priest, Donald Ferland, Dora Waldin, Lisa Bartolet, and Elsie Bennett Kappler -- without whose spirit, enthusiasm, and humor not much would be possible.

MARY L. MORRISSEY

#### NEWS OFFICE

Franco Modigliani's Nobel Prize and Ronald McNair's death in the crash of the space shuttle Challenger were the apex and nadir of the disparate events of 1985-86 that involved the MIT News Office.

Poles apart emotionally, those events nevertheless are of the same genus -- news, a category which also included the divestment issue, the shantytown on Kresge Oval and the arrests of some students there, coverage in the New York Times of MIT's moves "to strengthen arts and humanities," the SDI debate, Project Daedalus' proposed human-powered flight from Crete to the Greek mainland, the dedication of the Wiesner Building, a city of Cambridge investigation of security at our research reactor, the Institute's Quasquicentennial, the appointment of a faculty member to the commission that investigated the Challenger disaster, reports by faculty committees on the military presence at MIT and at Lincoln Laboratory, and the formal opening of the new VLSI laboratory.

Many of these events have very long half-lives. Two examples: The News Office continued to receive requests for photos and information on Professor Modigliani for several weeks after the Nobel announcement was made. The same was true of the Report of the Ad Hoc Committee on the Military Presence at MIT.

Tech Talk, under editor Joanne Miller, Assistant Director of the News Office, underwent some changes. The listing by the Personnel Office of job openings at the Institute became a special pull-out section of Tech Talk. The new format provides the Personnel Office with a four-page publication that can be distributed with Tech Talk or on its own in weeks when Tech Talk is not published. The jobs listing can also be sent to employment agencies as a separate publication. The change also benefits Tech Talk by making available for general news about one additional page per issue that had been devoted to the "Positions Available" section. Other Tech Talk changes include a new column, "Here and There," which provides a special focus on personal accomplishments and feature items. The new column is written by Assistant Director Charles H. Ball, who continues to pay special attention to the activities of the Schools of Architecture and Planning, Humanities and Social Science, and the Sloan School of Management.

During the past year the News Office has added an additional facet to its mission and is providing direct support to specific objectives of the admissions and development programs of the Institute. The office maintains its steady flow of press releases on MIT's activities in science, the arts -- an area for which Assistant Director China Altman is responsible -- engineering, management, and the humanities. An example of direct support for the admissions objective is the assignment undertaken by Ms. Altman, in addition to her responsibilities in the arts area, to call special attention to the record high number of women now at MIT. Ms. Altman, accompanied by Shawna Vogel '86, who worked as a News Office intern in 1985-86, visited several news outlets in New York City in June, calling attention to the role of women at MIT.

A major News Office event in the past year was the appointment in June of a new director, Kenneth D. Campbell, to succeed Robert M. Byers, who was director of the office for 14 years. Mr. Byers, recognized for his extensive knowledge of national science policy and his ability in the area of science communication, is now executive staff writer for MIT's president and other senior officers of the Institute.

Mr. Campbell, a 1962 graduate of Yale University, was a journalist for 13 years with the Washington Evening Star, United Press International and the Boston Globe. Since 1975 he has had extensive experience in public relations and management consulting.

Other personnel changes in the News Office include the retirement of Calvin D. Campbell, photojournalist for Tech Talk since 1974, and the promotion to Associate Director of Robert C. Di Iorio, a member of the staff since 1973.

In all its activities, the News Office continued to benefit from the industriousness and creativity of support staff members Lynn S. Heinemann, Sharon Davis, and Eugene de Mesne.

ROBERT C. DI IORIO

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## Career Services and Preprofessional Advising

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The clouds which gathered over the economy in 1984-85 persisted through 1985-86, complicating the plans of employers and of graduating students. Each quarter there were signs the sun might be coming out, encouraging employers to continue to interview on campus, but they were slow to make offers. The number of offers students and employers reported to us trailed last year's figures in most fields of engineering. The down turn was particularly noticeable in chemical and mechanical engineering. In chemical engineering there were fewer seniors looking for work because fewer sophomores have been choosing chemical engineering since the collapse of the oil cartel in 1982, but students in mechanical engineering felt the sting of fewer openings and some were without jobs at graduation. Three fields in which the number of offers was up last year were aeronautics and astronautics, civil engineering, and computer science, reflecting, no doubt, the rise in defense spending, the current construction boom, and the increased dependence on computers (which have been getting cheaper and cheaper) in every walk of life.

The following table shows how the number of offers reported nationwide to the College Placement Council has risen and fallen in different fields since 1980, when oil prices were still on the way up. The table compares the number of offers year by year in each field with the number offered in 1980 (=100). The index for 1986 is preliminary, based on the number of offers reported through March compared with the number reported through March last year.

National Job Offer Index for Graduating Seniors in Six Disciplines

	1980	1981	1982	1983	1984	1985	1986
Aeronautical Eng.	100	118	94	74	69	109	122
Chemical	100	106	57	16	30	32	26
Civil	100	106	56	21	28	33	42
Electrical	100	97	90	75	93	99	73
Mechanical	100	100	69	37	47	55	41
Computer Science	100	112	126	100	147	148	105

It has been a turbulent period for many industries. The most obvious casualty, of course, has been the oil industry, which has reduced its capital spending in the United States by nearly \$50 billion since 1982. The drop almost matches the increase in defense spending over the same period. Meanwhile, the chemical industry, facing worldwide competition, employs less people than it did ten years ago. Builders of manufacturing equipment have been losing business to the Europeans and the Japanese. The automobile industry has been inviting foreign manufacturers to help supply its new lines of small cars. The semiconductor industry, notoriously cyclical, has been experiencing the worst downswing in its history. The computer industry, in which enormous sums have been ventured, is suffering from its success; the price of computers has fallen precipitously and there are too many makers on the market. Even the defense sector has been eyeing the future nervously. Gramm-Rudman has put a crimp on defense spending as well as on other parts of the federal budget and notwithstanding the Strategic Defense Initiative total defense outlays for research, development, test, and evaluation and for procurement are not expected to exceed greatly their present level.

These factors were mirrored in the way companies came recruiting this year. Three examples: only one automobile manufacturer came looking for design engineers; for the second year in a row IBM recruited only in the fall; and while some defense companies came on more strongly, others drew back.

If students have not been left in the lurch by these changes -- and on the whole they have not been -- it is partly because they, like everyone else, have been watching what has been happening and partly because new opportunities for technical graduates keep appearing. While the manufacturing sector has been in disarray, the service sector has been booming. Two service industries which were eager to hire technical graduates this year (as well as graduates in management and in the humanities and social sciences) were management consulting and banking. We were visited by a host of consultants and bankers with technical degrees from MIT who came looking for more folk like themselves. They ranged from a management consultant with a bachelor's degree in biology to two Wall Street traders with doctorates in physics. The importance of the service sector as an employer of technical graduates is likely to increase.

All in all, 395 companies and government agencies recruited through the Office of Career Services and conducted 8978 interviews. This compares with 431 employers coming recruiting, and 9012 interviews, in 1984-85. At the bachelor's level salary offers to MIT students rose sharply in dollar amount in civil engineering and rose by more than the inflation rate in mathematics, materials science and engineering, aeronautics and astronautics, computer science, and chemical engineering. Offers trailed the inflation rate in electrical and mechanical engineering. Offers to masters in engineering were generally up by more than the inflation rate. Offers to doctoral candidates were up by more than the inflation rate in electrical engineering and materials science but stayed at last year's dollar figures in chemical and mechanical engineering.

The boom in the construction industry made it a good year for architects as well as for civil engineers, and the outlook was bright for graduates in urban studies and planning. The problems of rapid growth in some parts of the country and of "deindustrialization" in others and a renewed concern with the environmental and social impacts of industrial activity have raised many public policy questions. As a New York Times article put it, speaking of the political implications, "the battlegrounds are becoming more sophisticated, with planners handling many of the issues."

The Office responded to a surge of requests for well-trained architects by cosponsoring a Job Fair with the Harvard Graduate School of Design. This was a three day event in April at which some of Boston and New York's top firms, in a manner that is uncharacteristic of the way design firms usually find new staff, came to MIT and Harvard to recruit.

Also in April the Office joined forces with the Schools of Engineering and Management, the MIT Enterprise Forum, the Sloan Technology/Venture Club, and the MIT Alumni Association to organize a one-day conference to introduce students and alumni to opportunities in small businesses. The morning was devoted to hearing six representatives of small businesses talk about the rewards (and hazards) of working for a small company. Fifteen companies manned tables at a job fair in the afternoon. The program was well attended, suggesting that it was a venture that should be repeated. Thanks are due to the companies who participated and to the following who sparked a stimulating discussion at the morning session: Steven H. Chansky, '67; Kevin G. Curran, Class of '81; Dr. Arthur S. Obermayer, '56; James D. Richards, '77; Richard E. von Turkovich, '82; and Dr. Heidi R. Wyle, '84.

#### Defense and Nondefense Employment

The Office exists to help students and alumni with every kind of career objective -- those who want to make lots of money and those who care little how much they make so long as the work is rewarding, those who want to work on military projects and those who want to have nothing to do with weapons systems. During the year the Office spent considerable time working with students, faculty, and others interested in evaluating the impact of defense work at MIT and in the national economy and in identifying nondefense employment opportunities. We provided data to the Kaysen Committee on the placement of MIT graduates, suggested employers for a career fair organized by Student Pugwash and participated in panel discussions on nondefense employment, shared information on nondefense companies with the Boston-based Massachusetts High Technology Professionals for Peace, and contributed a section to a National Research Council report on the impact of the defense spending on nondefense engineering labor markets. Sorting graduating students by the business of their employer one finds that an increasing number of MIT graduates in science and engineering have been going with firms engaged in government-contract work, but that the number going with firms selling to a commercial market continue to be a majority. In 1984-85 60.5 percent of graduates in science and engineering joined firms (or divisions of firms) in the latter category, compared with 68.0 percent in 1980-81; 26.9 percent joined firms (or divisions of firms) doing government-contract work, compared with 21.6 percent in 1980-81.

#### Medical School

Bucking a national decline in the number of applicants to medical school, MIT fielded 123 candidates in 1985-86 compared with 114 in 1984-85 (which was also an increase over the previous year). Of the 123, 88 were undergraduates, 10 were graduate students, and 25 were alumni. Preliminary returns indicate that 73 of the undergraduates (83 percent), 8 of the graduate students (80 percent), and 16 of the alumni (64 percent) were accepted.

#### New Associate Director

In the last weeks of the year we welcomed a new associate director, Ann Davis Shaw, whose initial responsibility will be to help underrepresented minority students find professional summer jobs. Relevant work experience contributes importantly to an education for the professions and by multiplying work opportunities we hope we can encourage more minority students to pursue an MIT education. We wish her every success.

ROBERT K. WEATHERALL

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## Medical Department

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The Medical Department will remember 1985-1986 as a year of transition. It began with a newly approved set of Bylaws, a new departmental governance structure -- the Medical Management Board and its associated Executive Committee and Hospital Board -- and a new management team, as the Medical Director, Dr. Melvin H. Rodman was enjoying a year's sabbatical. During the year, Dr. Rodman announced his retirement to be effective June 30, 1986; Laurence H. Bishoff, Executive Director and Acting Department Head, resigned at the end of November; and Dr. Michael A. Kane, Acting Medical Director, was appointed Acting Department Head. On June 21, 1986, after a national search in which the credentials of more than 75 highly qualified applicants were reviewed, Dr. Arnold N. Weinberg was appointed as the new Medical Director.

Dr. Weinberg is Professor of Medicine at the Harvard Medical School, Vice Chancellor of the Department of Medicine at the Massachusetts General Hospital, and an internationally recognized expert in infectious disease. He has extensive experience as a medical educator and an administrator. From 1971 through 1975, he was Chief of Medicine at The Cambridge Hospital. He will begin his tenure in the Department in the fall of 1986.

The potential distraction of leadership changes did not deter new initiatives. There were concerted efforts to improve Medical Department programs for and outreach to the student community. In response to concern about the AIDS "epidemic", a working group led by Dr. Mark Goldstein, Chief of Student Health Services, and Dr. John Moses, Chairman of the Department's Infection Control Committee, developed written information about AIDS and its transmission and organized presentations on the subject to student and employee groups throughout the Institute. Another working group, which included members of the Office of the Dean for Student Affairs and the Institute Personnel Department, met with the Acting Medical Director throughout the year to share information and concerns about AIDS and to coordinate additional educational programs.

In March, Ms. Janet H. Van Ness joined the Department as Director of the Health Education Service. Before coming to MIT, she was the founder and coordinator of the Employee Assistance Program at Harvard University. Her initial mandate was to expand and improve programming efforts targeted at the student community. A major needs assessment has been completed and new programs will be introduced during R/O Week. There will be a cycle of student-centered programs geared to the academic year.

An extended search process (by some reckoning as long as five years) ended this spring with the determination that Dr. Alan M. Ducatman would assume the role of Chief of the Environmental Medical Service beginning July 1, 1986. Dr. Ducatman, board certified in both internal and occupational medicine, has extensive experience with a broad variety of environmental hazards in industry and in the military. He was most recently Director of the Professional Occupational Health Branch of the Navy Environmental Health Center. As part of his responsibilities, Dr. Ducatman will establish a hazard assessment program as a clinical service in the Medical Department. Employees and students concerned about environmental factors affecting their health will be offered consultation and assessment. This program will re-establish the clinical arm of the Environmental Medical Service, initially provided by its founding director, Dr. Harriet Hardy.

The loss of Mr. Bishoff in mid-year left the Department without its most experienced senior manager. As an interim step, a departmental Management Committee, including Linda L. Rounds, Assistant Director for Finance and the MIT Health Plans; George N. Petievich, Assistant Director for Operations and Systems; and Dr. John Christian Kryder, Physician and Special Assistant to the Executive Director, was appointed to help conduct the business of the Department in an orderly and effective manner through the period of transition. Due to the cooperative efforts of these individuals, that goal is being achieved. With the appointment of Dr. Weinberg, a search for a new Executive Director has just been launched. By the end of 1986, the core management team comprised of the Medical Director and Executive Director should once again be in place.

While the contributions of the Management Committee's members have been among the most visible in the Department this year, many individuals have taken on additional responsibilities in order to continue the Department's effective functioning. Dr. H. Walter Jones was named Chief of Medicine at the beginning of the year. In addition, he chaired the Advisory Committee on the Search for the new Medical Director and was acting chairman

of the Credentials Committee. Dr. Martha Pedraza replaced Dr. Jones as chairman of the Department's Utilization Review Committee. Kathleen L. Marshall, Assistant to the Executive Director, provided effective, cheerful, and discreet staff support for the Management Committee, the Search Committee, and numerous other entities. Dr. William A. Ruth became coordinator of the Medical Department's educational activities. This year these included our continued participation in the Mount Auburn Hospital Primary Care Training Program and the offering of a Physical Diagnosis Program to Whitaker College students in medical engineering and medical physics. Dr. Kryder, in addition to continuing a major benefits study for the Institute, coordinated the activities of the Off-Hours Clinic and the hospital liaison program.

There have been several improvements in the Department's medical services over the past year. Dr. Bruce Wood, head of Podiatry at the Brigham and Women's Hospital, joined the Department and in six months has already had to double his commitment of time because of the popularity of his services. Nurse practitioners are now available to see patients on an urgent/unscheduled basis beginning at 7:00 a.m. weekdays. Medical Department physicians and Mount Auburn Hospital residents have been incorporated into the coverage of the Off-Hours Service. In addition, 24-hour (Holter) EKG monitoring is now available at the Department. In the near future, other procedures now provided at outside hospitals, including ultraviolet light therapy and echocardiography, will be offered in the Department.

#### Staff Changes

##### Appointments

Susan J. Bennett  
Ellen A. Branfman  
Maureen Dickey  
  
Sharon K. Edwards  
Lawrence T. Geoghegan  
Michael L. Glover

Kathleen L. Marshall

Katherine M. Martien  
Elizabeth T. Martin  
Mary E. Murray  
Laura A. Nicholas  
Mary E. Nolen  
Allan R. Oseroff  
Barbara K. Prazak  
Donna K. Spencer  
Kenneth A. Stampfer  
Susan V. Stanton  
Charles W. Tracy  
Bonnie L. Weeks  
Bruce T. Wood  
Janet H. Van Ness

Dental Hygienist  
Audiologist  
Patient Care Coordinator,  
Inpatient Unit  
Dental Hygienist  
Surgeon  
Manager for Marketing and  
Member Services  
Assistant to the Executive  
Director  
Pediatrician  
Consultant in Pathology  
Manager, Financial Services  
Physical Therapist  
Dermatology Nurse Practitioner  
Dermatologist  
Physician  
Audiologist  
Ophthalmologist  
Surgeon  
Dentist  
Industrial Hygiene Engineer  
Podiatrist  
Director of Health Education

##### Resignations

Steven A. Adelman  
Joyce M. Aijala  
Susan J. Bennett  
Joy Biller-Pirog  
Laurence H. Bishoff

Ann R. Butman

Joseph F. Gerstein  
Julius E. Goldblatt  
Robert F. Golinveaux  
Lois High  
Louis Kertzman  
Constantine Maletskos  
Gioia M. Morongell

James P. Nolan

Post Doctoral Psychiatry Fellow  
Inpatient Nurse  
Dental Hygienist  
Inpatient Nurse  
Executive Director and Acting  
Department Head  
Manager, Accounting and Billing  
Services  
Physician  
Surgeon  
Pharmacist  
Inpatient Nurse  
Sanitary Consultant  
Bio-Physicist  
Manager for Marketing and  
Member Services  
Consultant in Pathology



Stephen Piccolo  
Ruth G. Pucciarelli  
Richard Schatzki  
Susan V. Stanton  
Gay E. Torresyap  
Roland E. Vanaria  
Michael E. Wiedman

Industrial Hygiene Engineer  
Medical Records Consultant  
Radiologist  
Surgeon  
Dental Hygienist  
Dentist  
Ophthalmologist

#### Social Work Service

In the past year, utilization of the Infirmary by many older and more infirm patients has created a new type of pressure on staff availability due to the labor intensive quality of the work with such patients. The Social Work Service staff hopes to meet the clinical demands without undue delay or inconvenience to clients.

This year saw the resumption of activity in the Institute Personal Assistance Program Advisory Committee under the leadership of Professor Thomas Sheridan. The Advisory Committee is concentrating upon the problem of responding in a timely, adequate, and supportive manner to severely troubled employees. The Institute Personal Assistance program continues to provide clinical services to a broad range of employees who present with problems ranging from alcoholism to personal and family problems. Training and orientations have been provided to supervisors and managers at MIT and the Draper Laboratory. Several of the training sessions have been carried out in cooperation with the Personal Development Office.

The Social Work Service continues to play an important role in the life of the MIT community. The Service clinicians are involved with supervisors, deans, minority students and administrators, Campus Police, and Personnel officers. Specific activities include ongoing projects with the Technology Child Care Board, the Office of Minority Education, and the Personnel Department.

#### Health Education Service

Highlights of the Service's activities in the last year include coordination of the Medical Department's largest ever IAP offering, significant expansion of the resource center and library, considerable enlargement of our community resource network, and initiation of a health education needs assessment for the undergraduate population. Equally important in the face of limited staffing was the maintenance of several core health education programs which continued to be well received by the MIT community. During the January 1986 IAP program, 61 lectures focused on a wide range of such timely issues as mental health, women's health, AIDS, the environment, and preventive medicine. A total of 1345 people attended these sessions.

#### Psychiatry Service

The total number of admissions to outside mental hospitals and the total number of days hospitalized continue to decline, resulting in a decrease in the average number of days per patient and the number of days per admission. The total number of patients admitted to the MIT Infirmary also declined. There has been an increase in the average number of days per patient and per admission. This is clearly due to the decision to treat in the MIT Inpatient Unit some patients who in the past would have been sent to outside hospital facilities.

#### Environmental Medical Service

Within the past year, the documents required by the Massachusetts Division of Environmental Quality Engineering for the VLSI facility in Building 39 were submitted and approval to operate was received. Considerable industrial hygiene officer time was devoted to establishing criteria and controls to ensure that both operators and the environment were adequately protected. A large scale tritium experiment at the Bates Accelerator introduced a significant impact on available manpower for radiation protection during the extended test period. This experiment was considered an overall success; and, although it lasted significantly longer than anyone predicted, it was conducted safely.

The interrelationships between groups within the Environmental Medical Service and the good working relationships with other departments continues to produce excellent results. The Industrial Hygiene Office and the Biohazard Assessment Office groups worked jointly on several projects, including an evaluation of ethidium bromide neutralization procedures and an analysis of the dispersion capabilities at the Linac prior to the tritium experiment.

Training sessions associated with departmental programs and Right To Know seminars have and will continue to expand. There continues to be a need to incorporate such training into the regular graduate and undergraduate programs. At present, there are only a few instances where formal teaching by EMS personnel has been incorporated. Many members of the Medical Staff hope to work with Dr. Ducatman to devise ways to significantly expand these efforts within the educational programs of the Institute.

Associations with the Draper Laboratory and Whitehead Institute have continued to develop well. EMS activities at both locations have stabilized and no significant increase in demand for services is currently anticipated.

Additional developments or changes within the past year included expansion of the entomology activities with EMS, development of guidelines for contractors involved in work at MIT, completion of several applied research projects, and an expansion of our relationship with members of the Industrial Liaison Program.

#### MIT Health Plan

The MIT Health Plan has had a successful year despite the loss of Mr. Bishoff and Gioia M. Morongell, who had ably supported many of the Plan's administrative activities for five years as the Manager of Marketing and Member Services. In November, Michael L. Glover was appointed to fill the vacancy caused by the resignation of Ms. Morongell. Mr. Glover brings extensive knowledge of MIT and experience in benefits administration from his former position as Assistant Manager for Benefits Communication in the MIT Personnel Office.

More intense competition in the health care industry is beginning to have a noticeable effect on Plan membership. By year-end, the Plan had 200 fewer members than one year ago, but only forty fewer contracts. As of June 1, 1986, Plan membership stood at 8,501 with 4,218 contracts in force, representing an average of 2.02 members covered under each contract. The number of individual contracts declined by nearly 120. The statistics reflect an increased concern among our members for convenience when seeking health care services on behalf of their family members. The proliferation of HMO alternatives in suburban areas appears to have been responsible for the loss of family memberships in the Plan during the past year. The administrative staff are currently formulating various strategies to maintain and expand membership in the Plan.

Hospital utilization by Plan members has remained under control at 340 days per 1,000 members. The Plan's financial results will be positively affected by the inpatient hospital experience of our members.

A major improvement in claims processing occurred during the past year with the implementation of an automated tracking system. The claims management system has been installed on the Department's local area network. Claims backlogs and missing paperwork now seem like a distant memory to the claims processing staff. There has been a significant improvement in the level of service provided to members. In addition, the system captures the data necessary to identify opportunities for containing external costs by bringing medical services in-house.

MICHAEL A. KANE, M.D.

This was a dynamic and eventful year at the MIT Press. We established a European editorial office in Oxford, England, and launched a program to acquire original properties from the United Kingdom and Europe to support our growing core lists in Computer Science/Artificial Intelligence; Cognitive and Brain Sciences; Economics and Management; Architecture and the Arts. We concluded arrangements with the Institute to consolidate all the MIT Press operations in newly renovated quarters at 55 Hayward Street in Kendall Square. We experienced record sales in the MIT Press bookstore of \$220,000, despite being in the center of a construction site all year. We successfully launched our most ambitious reference book undertaking, The Encyclopedia of Materials Science and Engineering, and were able to develop new telemarketing techniques in support of this project. We successfully weathered the financial disaster of losing our most important and profitable journal, Cell, during the year. At the same time, we negotiated contracts for four potentially important new journal properties: Quarterly Journal of Economics; International Journal of Supercomputer Applications; Assemblage; Materials Processing Report. We closed down our Computergraphics typesetting operation, a move designed to take advantage of more cost-effective typesetting using outside suppliers.

Net sales from our book operation were up \$1 million, or 17 percent over fiscal year 1985. Sales in the Journals division dropped significantly, with the termination of Cell, yet we managed to break even. The Press closed its fiscal year with a \$17,000 net gain from operations.

We published 153 titles: 111 original publications, and 42 paperbacks reprinted from our own hardcover backlist. While we published 13 percent more new books compared with Fiscal 1985, unit sales were up 22 percent. We sold 514,000 copies of our books this year compared with 464,000 last year.

### MIT AUTHORS

Belsley and Kuh:	<u>Model Reliability</u>
Ben-Akiva and Lerman:	<u>Discrete Choice Analysis</u>
Berwick:	<u>The Acquisition of Syntactic Knowledge</u>
Blanchard, Dornbusch, Layard:	<u>Restoring Europe's Prosperity</u>
Carey:	<u>Conceptual Change in Childhood</u>
Chomsky:	<u>Barriers</u>
Fisher:	<u>Indexing, Inflation, and Economic Policy</u>
Harvey:	<u>Computer Science Logo Style</u>
Horn:	<u>Robot Vision</u>
Lieserson:	<u>Advanced Research in VLSI</u>
Liskov and Gutttag:	<u>Abstraction and Specification in Program Development</u>
Osherson, Stob, Weinstein:	<u>Systems That Learn</u>
Pinker:	<u>Visual Cognition</u>
Siebert:	<u>Circuits Signals and Systems</u>
Smith:	<u>Military Enterprise and Technological Change</u>

### SOME OF OUR BESTSELLERS FROM THIS YEAR'S LIST

Bache:	<u>IBM's Early Computers</u>
Chomsky:	<u>Barriers</u>
Forsyth:	<u>Buildings for Music</u>
Harvey:	<u>Computer Science Logo Style</u>
Haugeland:	<u>Artificial Intelligence: The Very Idea</u>
Hillis:	<u>The Connection Machine</u>
Jevons:	<u>Fatal Equilibrium</u>
Kitcher:	<u>Vaulting Ambition</u>
Krinsky:	<u>The Synagogues of Europe</u>
Napier:	<u>Natural History of the Primates</u>
Van Riemstijk and Williams:	<u>Introduction to the Theory of Grammar</u>

COMPARATIVE OPERATING RESULTS (in thousands)

	<u>Fiscal Year</u> <u>1986</u> <u>Actual</u>	<u>Fiscal Year</u> <u>1985</u> <u>Actual</u>	<u>Fiscal Year</u> <u>1984</u> <u>Actual</u>
Total Net Book Sales	\$6,938	\$5,930	\$5,353
Cost of Sales	3,034	2,666	2,423
Gross Margin on Sales	3,904	3,264	2,930
Other Pub. Income	38	29	31
Bookstore Net	40	30	30
Total Income	3,982	3,323	2,991
Operating Expense	3,966	3,407	3,092
Net Books Division	16	( 84)	( 101)
Journals Surplus	1	101	157
NET	\$ 17	\$ 17	\$ 56

The Press received approximately \$53,000 in subventions aiding the publication of four of its titles during the past year. Sources of subvention included the Graham Foundation for Advanced Study in the Fine Arts and the National Endowment for the Arts. These grants helped make possible the publication of Dennis: Court and Garden; Lehiste & Ivic: Word and Sentence: Rhapsody in Serbocroatian; Light & Schuller, eds: Political Values and Health Care; and Macrac-Gibson: The Secret Life of Buildings.

Press books won several notable awards this year. Carol Krinsky's Synagogues of Europe: Architecture, History, Meaning, co-published with the Architectural History Foundation, received the National Jewish Book Award in Visual Arts. The Society of Architectural Historians awarded the Alice David Hitchcock Award to The Law Courts: The Architecture of George Edmund Street, by David Brownlee, another Architectural History Foundation co-publication. Finally, Rings: Discoveries from Galileo to Voyager by James Elliot and Richard Kerr was named Astronomy Book of the Year for 1985 by Mercury Magazine, a publication of the Astronomical Society of the Pacific.

Faculty serving on The MIT Press editorial board in 1985-1986 were Professors Harold Abelson, Peter Elias, John de Monchaux, Loren R. Graham, Richard Held, John P. Longwell, Daniel Osherson, Robert Solow, and Carl Wunsch. Jay Lucker, Constantine B. Simonides, and Frank Urbanowski served as ex-officio members. Professor Ascher Shapiro served as chairman of the editorial board.

The MIT Press management board met twice during the year. Members of the board are Christopher T. Walsh, Head, Department of Chemistry; Arthur L. Singer, Jr., Vice President, Alfred P. Sloan Foundation; Alvin J. Silk, Associate Dean of the Sloan School; Ann F. Friedlaender, Dean, School of Humanities & Social Science; Jeremiah Kaplan, President, Macmillan Publishing Co., Inc.; Norman Pomerance, Vice President, General Books Group, Harper & Row; Jack Schulman; and W. Bradford Wiley, Chairman, John Wiley & Sons, Inc. Professor Shapiro, chairman of the editorial board, and Mr. Urbanowski, Director of the MIT Press, are ex-officio members. Mr. Simonides, Vice President in the Office of the President, is chairman of the management board.

BOOK PROGRAM

The complexion of our list continues to reflect our intention to devote most of our resources to building depth in our programs in architecture and design arts, computer science and artificial intelligence, cognitive science and linguistics, economics and philosophy, with the balance of our efforts devoted to publication of important works in science, technology and society, and in science and engineering.

Among the noteworthy books by non-MIT people from our scholarly and professional program were:

Bashe et al.	<u>IBM's Early Computers: A Technical History</u>
Baumol	<u>Superfairness: Applications and Theory</u>
Bloch	<u>The Principle of Hope</u>
Churchland	<u>Neurophilosophy: Toward a Unified Science of the Mind-Brain</u>
Cooper	<u>Economic Policy in an Interdependent World</u>
Delaporte	<u>Disease and Civilization: The Cholera in Paris, 1832</u>
Gabriel	<u>Performance and Evaluation of LISP Systems</u>
Kane	<u>The Gathering Crisis in Federal Deposit Insurance</u>
Kornai	<u>Contradictions and Dilemmas: Studies on the Socialist Economy and Society</u>
MacCormac	<u>A Cognitive Theory of Metaphor</u>
May	<u>Logical Form</u>
Salmon	<u>Frege's Puzzle</u>
Tugendhat	<u>Self-Consciousness and Self-Understanding</u>
Vernez Moudon	<u>Built for Change: Neighborhood Architecture in San Francisco</u>
Wang	<u>Beyond Analytic Philosophy</u>

New hardcover books for trade and general audiences included:

Banham	<u>A Concrete Atlantis</u>
Corn, ed	<u>Imagining Tomorrow</u>
Dennis	<u>Corn and Garden</u>
Foell & Nenneman	<u>How Peace Came to the World</u>
Haugeland	<u>Artificial Intelligence: The Very Idea</u>
Jevons	<u>The Fatal Equilibrium</u>
Kitcher	<u>Vaulting Ambition</u>
Nickerson	<u>Using Computers</u>
Nye	<u>Image Worlds</u>
Yoshino & Lifson	<u>The Invisible Link: Japan's Sogo Shosha</u>

Books published primarily as texts included:

Ben Akiva & Ierman	<u>Discrete Choice Analysis</u>
Blaizot & Ripka	<u>Quantum Theory of Finite Systems</u>
Harvey	<u>Computer Science Logo Style</u>
Kennedy	<u>A Guide to Econometrics, 2nd edition</u>
Van Riemsdijk	<u>Introduction to the Theory of Syntax</u>

Editors in the Acquisition department include: Frank Satlow (Engineering & Computer Science); Laurence Cohen (Sciences, Engineering, Linguistics & Philosophy); Roger Conover (Architecture and Design Arts); Mark Rakatansky (Architecture and Design Arts); Terry Vaughn (Economics and Management); Robert Bolick (Oxford); Harry & Betty Stanton (Cognitive Science, Bradford Books); Terry Ehling (Computer Science); and Charlotte Richie (Assistant Acquisitions Editor).

#### BOOK PRODUCTION

Under the direction of Helen Osborne, managing editor, and Dick Woelflein, production manager, the editorial and production departments continued to add quality to our publications. The design department, under Diane Jaroch, upheld the Press tradition of award-winning jacket and book design, garnering honors from the New England Book Show, the Association of American University Presses, and the Art Director's Show of Boston.

## BOOK SALES

Under the direction of Tom McCorkle, marketing manager, regular domestic sales increased 12.7 percent over last year. Sales in the United States and Canada by distribution channel were as follows:

<u>Customer Type</u>	<u>Fiscal Year 1986</u>	<u>Fiscal Year 1985</u> (in thousands)	<u>Fiscal Year 1984</u>
College Bookstore	\$1,280	\$1,154	\$1,105
Retail Bookstore	1,440	1,275	1,159
Wholesale/Jobber	1,420	1,250	1,163
College/University Library	110	129	136
Direct Mail	520	426	412
To Individuals	<u>570</u>	<u>500</u>	<u>357</u>
Totals	5,340	4,734	4,332

This has been another good year, with healthy increases both domestically and internationally. Especially encouraging is the increase in the number of books we sold, from 465,000 to 514,000, or about 22 percent.

## INTERNATIONAL SALES AND SUBSIDIARY RIGHTS

International book sales increased 10 percent in FY 1986. Sales increased in many of the major geographical areas did not match the 13 percent increase recorded for the U.S.A., but Canada and the Asian countries with booming economies -- Korea, Taiwan, and Hong Kong -- produced sales increases higher than those achieved in the U.S.A. The average increase in the three countries was 62 percent, ranging from a low of 53 percent in Taiwan to a high of 74 percent in Hong Kong. Total sales from these three countries are still small, only \$66,000 in FY 1986, but with progress being made to curb book piracy, and assuming continued strong economic growth, the prospect for substantial growth in the area is good.

### International Book Sales FY 1984-1986

	<u>Fiscal Year 1986</u>	<u>Fiscal Year 1985</u>	<u>Fiscal Year 1984</u>
Australasia	\$ 38,900	\$ 32,300	\$ 35,000
Canada	272,900	238,800	229,000
Japan	292,100	284,900	251,000
Rest of Asia/Other	197,200	172,100	109,100
Latin America	21,200	24,500	47,500
UK/Europe/Africa/Mideast	<u>724,300</u>	<u>656,300</u>	<u>560,600</u>
Totals	1,546,600	1,408,900	1,232,200

The major disappointment of the year was Japan. Although unit sales were up 11 percent, dollar sales were up only 3 percent. The unit sales increase was due to large quantity purchases of new paperback linguistics titles -- lots of books, but not too much money per book. Indications are that the market for academic books in Japan has reached its maximum and will not grow further in the near future. Our sales there are almost totally dependent on money available for book purchase by academic libraries. Library budgets in Japan are leveling off and may actually drop in the 1990s, when enrollment in universities is expected to decline because of demographic factors. In the future, dollar sales increases in Japan will be achieved only through price increases and from publication of the occasional high-priced title that is of special interest in the Japanese market.

In subsidiary rights, 14 titles sold to bookclubs and 20 translation contracts were signed. Total income for subsidiary rights was up 30 percent over FY 1985.

### Subsidiary Rights Income FY 1984-1986

	<u>Fiscal Year 1986</u>	<u>Fiscal Year 1985</u>	<u>Fiscal Year 1984</u>
Translation Rights	\$36,296	\$28,511	\$26,592
Book Club Rights	20,152	12,533	11,224
Reprint Rights	<u>20,555</u>	<u>18,334</u>	<u>19,979</u>
Totals	77,004	59,379	57,795

## DIRECT MAIL AND PROMOTION

Under the direction of Brooke Stevens, Promotion Manager, there was considerable improvement across the board in direct mail selling, text marketing, attendance at exhibits, and publicity.

Direct mail sales for the year were \$526,000, a 25 percent increase over last year. The Press mailed out four subject catalogues, a sale catalogue, and nine brochures to 537,000 people. These mailings were in addition to the three seasonal catalogues, and the special direct mail campaign as part of the intensive promotion of the \$1,500 Encyclopedia of Materials Science and Engineering.

Text promotions this year were greater in number than any previous year: 23 promotional pieces were mailed to 85,000 professors, and text sales topped the \$1.5 million mark.

In Fiscal 1986, the booth exhibit program increased by almost 100 percent. The exhibits program continues to pay for itself and is increasingly becoming a healthy money maker, as it continues to draw attention MIT Press books.

The Press is attending more professional meetings than in prior years, particularly in computer science and in the cognitive sciences.

Press books continued to receive favorable reviews in a number of major publications. Some of the highlights include: The New York Times Book Review reviewed Carol Herselle Krinsky's Synagogues of Europe: Architecture, History, Meaning (co-published with the Architectural History Foundation; Philip Kitcher's Vaulting Ambition; John D. Stoeckle and George Abbott White's Plain Pictures of Plain Doctoring; Marshall Jevons' The Fatal Equilibrium; Dorothy Stein's ADA: A Life and Legacy; and Reyner Banham's A Concrete Atlantis. The Natural History of Primates by J. R. and P. H. Napier was reviewed by Scientific American. The New York Review of Books commented on Richard A. Etlin's The Architecture of Death: The Transformation of the Cemetery in Eighteenth Century Paris, Lester Thurow's The Management Challenge: Japanese Views, and Tegethoff's Mies Van Der Rohe: The Villas and Country Houses.

## JOURNALS

The Journals division had gross sales of \$1.7 million and closed the fiscal year at breakeven. Sales were 14 percent higher than last year.

Total circulation of the fifteen journals in the program was 39,500. Levels for all journals were higher than FY85.

Two new publications were launched in 1986. Materials and Processing Report, a monthly newsletter on materials science published in association with MIT's Materials Processing Center and NBER Macroeconomics Annual, edited by Stanley Fischer, MIT, a series of papers presented at an annual conference sponsored by the National Bureau of Economic Research. Four journals were accepted for publication in FY87: Quarterly Journal of Economics, Harvard University; Mountain Research and Development, International Mountain Society; Assemblage, a critical journal of architecture and design culture, press-owned; International Journal of Supercomputer Applications, press-owned.

Five journals published special issues in 1986: International Journal of Robotics Research, "Kinematics", edited by J. M. McCarthy; Journal of Interdisciplinary History, "The Evidence of Art: Images and Meaning History" edited by Theodore K. Raab and Jonathan Brown; International Organization, "Power, Purpose and Collective Choice: Economic Strategy in Socialist States" edited by Ellen Comisso and Laura D'Andrea Tyson; Computer Music Journal, "Tenth Anniversary Issue", edited by Curtis Roads; October, "Georges Bataille, Writings on Laughter, Sacrifice, Nietzsche, Un-Knowing" edited by Annette Michaelson and Rosalind Krauss. At least three of the issues will be published as hardcover books by various publishers.

Journals staff now totals fourteen, twelve full-time and two part-time employees. Julia Salas, production manager, Nancy Roberts, administrative assistant, and Lori White, office assistant, joined the staff in 1985.

FRANK URBANOWSKI

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## Personnel Office

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The past year proved to be a challenging and productive one. Additional new programs were offered for employee development, agreements were signed with four of the five unions, new recruitment programs were developed to help enlarge the pool of secretarial applicants, and the computational information systems were further strengthened.

Effective July 1, 1985, the Personnel Office assumed administrative responsibility for the Child Care Office. While the quality of child care services offered is held in high regard by child care professionals around the country, the ever-increasing demand for child care by members of the community requires that we be more creative in attempting to meet those needs.

There were several staffing changes during the past year. Kathleen Flynn was appointed as Programmer/Systems Coordinator in Faculty and Staff Information Services (FASIS), and Isaac Colbert, Manager of FASIS, was appointed as Assistant to the Vice President for Financial Operations, for Information Systems. Richard Higham left the Personnel Office to pursue a writing career. Patricia DePamphilis and Michael Glover left the Benefits Office, Ms. DePamphilis to meet the full-time demands of motherhood and Mr. Glover to assume responsibilities as Manager for Marketing and Member Services, MIT Health Plan. As a result of these two personnel changes and reorganization in the Benefits Office, two members of the support staff were appointed to administrative staff positions -- Sherry Capano as Benefits Assistant, Data Systems, and Julianne Kelly Castro as Benefits Assistant, Public Information. Kathryn Tighe left the Child Care Office and was replaced by Joanne De Siato as Child Care Administrator.

JOAN F. RICE

### PERSONNEL DEVELOPMENT

During 1985-1986, a total of 5,300 employees participated in Personnel sponsored programs including in-house training and development opportunities; presentations offered within laboratories, departments, and centers; and sponsorship for outside educational opportunities through the Tuition Assistance Program.

A wide variety of training and development opportunities were presented at the Institute. Fourteen new or revised programs were added in the training area addressing an assortment of job-related and career-related topics. In total, 41 different training programs were offered during the year and most of them were repeated several times.

Many of the presenters in the programs are members of the MIT community who continue to provide their time and expertise to the training effort.

SUSAN WARSHAUER

### COMPENSATION

#### Benefits Administration

Much of the focus of benefits administration during the past year has been to monitor and to respond to benefits legislation enacted by the Commonwealth of Massachusetts and the U.S. Congress. Of particular impact are the benefits changes required by the Deficit Reduction Act, the Retirement Equity Act, the Consolidated Omnibus Budget Reconciliation Act, and the pending Tax Reform Act.

Bay State Health Care was offered at MIT for the first time in January 1986, as a sixth health insurance option for active employees, with 213 faculty and staff enrolling in the plan. In addition, MIT now offers over-65 retirees and their spouses four options for health insurance supplements to Medicare, the primary health insurance coverage for retirees.



As a result of last summer's union negotiations, the Compensation Office implemented several changes in benefits for union personnel (except Campus Police), including improvements in group life insurance, in long-term disability, and a one-time, .7% per year of membership increase in benefits accrued under the Retirement Plan for Employees for all active members of that plan.

A handbook entitled Your MIT Retirement Benefits was completed and distributed this year. In addition, the Benefits staff passed the halfway mark in their task of revising and issuing the Summary Plan Descriptions for each benefit plan offered by MIT.

The Compensation Office designed and implemented a database to facilitate administration of the Tuition Assistance Program. In its early stages, the database has proved valuable in the daily operation of the plan and promises to more efficiently track data for utilization and budget projections.

During the past year, the Compensation Office conducted 40 workshop sessions for current employees, including retirement planning seminars, health enrollment workshops, and FRAP workshops. We also held 139 orientation sessions for new faculty, academic, research, administrative, support, and service staff. In addition, the Compensation Office responded to approximately 40,000 telephone calls and to the 4,000 faculty and staff per year who visited the office.

#### Wage and Salary Administration

The Compensation Office continued its work to provide fair and equitable salary administration across the Institute during the annual review process, and in the review and analysis of individual salary increase and promotion recommendations submitted by departments throughout the year. The annual review cycle begins with preparation for the Sponsored Research Staff Review early in October, and proceeds through the academic year to encompass the review of Support Staff, Faculty, Academic Staff, and Administrative Staff, concluding with year-end reports to the Executive Committee of the Corporation in early June. Through these annual merit reviews, approximately 8,000 individuals received consideration for salary adjustment this year, based on conditions as they exist in the appropriate marketplace, the Institute's outlook, and the relationship of the Institute's salary position to these conditions. Participation in approximately 35 salary surveys during the year, and particularly in the MIT Faculty Salary Survey, the national R & D Survey, and the MIT Administrative and Professional Salary Survey, enables us to assess the Institute's position to these markets, and to make informed recommendations to the Executive Committee for adjustments to the Institute's existing salary structures and pay ranges.

Twenty-seven universities participated in MIT's 1985-1986 nationwide Faculty Salary Survey. For each of MIT's three faculty ranks, the Institute's average salaries exceeded the overall averages of the 27 universities. Use of our IBM Personal Computer enabled us to provide extensive analysis of the Survey data to the School Deans and to other Senior Officers prior to the Faculty salary review in February.

Twenty-two universities and eight area employers participated in the Fall 1985 Administrative and Professional Salary Survey, conducted by our office. This survey, now in its eleventh year, surveys 40 benchmark positions on the administrative staff for comparison of average salaries, salary ranges, and similarity of organizational structures. The early completion of this survey in 1985 provided us with valuable data in planning our salary recommendations for 1985-86.

A total of 163 requests for reclassification on the Administrative Staff were received during the year: 80 requests to assess newly created positions; 19 promotional requests for individuals moving from Support Staff and Exempt; 35 requests to reevaluate existing positions and their salary ranges; and 29 requests for title changes. In order to review so many requests in a way that assures a sense of equity across the Institute, we have continued to rely on the organizational charts developed last year which display structures not only of departments, but of entire organizational areas. These charts have become an invaluable tool for Senior Officers in giving an overview of the departments which report to them, and in determining comparable structures in new departments. As positions are defined and/or redefined, we have updated position descriptions, based on material submitted by departments.

Salaries paid to members of the Support Staff continue to compare favorably to the local market of major Boston area employers. Salary ranges and the position standards developed several years ago by the Working Group on Office/Clerical Issues, continue to be useful, fair, and workable guidelines in reaching equitable decisions regarding individual Support Staff positions, and, in particular, in assessing requests for promotion within the Support Staff. The position standards contribute substantially to the use of all ranges within the Support Staff structure.

KERRY B. WILSON

## FACULTY AND STAFF INFORMATION SERVICES

The Faculty and Staff Information Services continued its work to provide information systems support to the Personnel Office and to consumers of personnel information throughout the Institute. In addition to the usual annual flow of approximately 12,000 personnel appointments and changes, a variety of other support services continue to be provided. These include preparation of documents for the annual review cycle, and maintenance of physical and electronic personnel records for approximately 8,000 campus based faculty and staff.

As the capabilities of our computational systems have enhanced the variety and sophistication of output reports, our role as a primary provider of demographic data and other special-purpose information has broadened. With the appointment this past year of a new Programmer/Systems Coordinator, Ms. Kathleen Flynn, additional strength can now be directed toward more fully serving the growing needs of administrators for personnel related information.

A new direction of potentially major significance was initiated with the participation of the Manager in the development of an Institute-wide strategic plan for computational support of business activities. Within that plan, a pilot project has begun with the goal of making personnel data accessible electronically to authorized administrators. The Faculty and Staff Information Services looks forward to assisting in the implementation of all phases of this project, and anticipates eagerly the day when the flow of paper is replaced by direct electronic communication with the rest of the Institute's administrative community. The implications of this pilot program for the way in which everyday tasks in our office might be accomplished in the future, are exciting. We are pleased to be among those who are trying to lead the effort to chart new directions in computing support for business activities at the Institute.

ISAAC M. COLBERT

## LABOR RELATIONS

On or about July 1, 1986, the Institute will subcontract the food service function of the Faculty Club and the Student Dining Halls. All bargaining unit employees who are members of the Hotel, Restaurant, Institutional Employees' and Bartenders' Union, Local #26, AFL-CIO will be terminated as employees of the Institute and hired by the new contractor. The two Institute/Union Agreements governing the relationship with these employees will remain in effect until June 30, 1987 under the terms of a successors and assigns clause. The Office of Labor Relations is currently negotiating with Union officials the precise details of the termination, and the employment conditions that will govern during the first year with the new contractor.

In February, the Research, Development and Technical Employees' Union filed a petition with the National Labor Relations Board to represent, in a professional unit, twelve senior technical artists in the Lincoln Laboratory. In addition, this union filed a second petition with the Board asking to represent a new separate bargaining unit of six employees classified as Service Assistants in the Athletic Department. The petitions were filed after this office denied the Union's request for voluntary recognition. There have been four days of hearings before the Board with many more to come. The Institute's position is that both groups of employees have job duties, working conditions, and benefits that are related to, and integrated with, other Support Staff members. The artists are only half the employees in this classification in the Support Staff, and are not assigned professional duties and responsibilities.

During September, two-year Labor/Management Agreements were signed covering 1,550 Service Staff employees in five separate bargaining units, of which four are international unions and one independent. Joan F. Rice, Director of Personnel, served as negotiator for two units, and the Manager of Labor Relations was negotiator for the other units. In March, this office signed a new three-year Agreement for the Lincoln Laboratory Guards with the Independent Union of Plant Protection Employees, Local #14, AFL-CIO. The wages and benefits agreed upon are comparable to those given to other employee groups. The right to manage was greatly strengthened by improved contract language. New entrance level hiring rates were established. The change in the length of this Agreement from two to three years will aid this office in the management of labor issues at a time of limited budgets and staffs while the work load continues to spiral upward.

The grievances and arbitrations continue at a high but stable level. The backlog of arbitrations has been reduced through a series of Union/Management meetings that reviewed and resolved many pending labor relations issues. Layoffs have been few in number and manageable. Labor relations teach-ins have

continued, but we find it difficult to maintain a reasonable schedule of meetings in proportion to the demands of the departments, centers, and laboratories for more "how-to" working groups sessions on basic labor issues.

JAMES J. FANDEL

## PERSONNEL SERVICES AND EMPLOYMENT

### Personnel Services

Personnel Services has the responsibility for the development and interpretation of policies and procedures, and for the coordination of personnel and employment matters.

Seven Personnel Officers, with defined organizational unit responsibilities, screen and refer candidates for positions, and work closely with supervisors and employees on organizational needs to improve the effectiveness of human resources. Personnel Officers have assisted in designing a recruitment program which includes a broader outreach from the Institute, and have continued their participation in the development and presentation of training programs.

### Employment Activity

A series of ongoing recruitment programs was developed and implemented to create a continuous flow of qualified applicants. These programs have resulted in a broader, more diverse pool of applicants being considered for positions at the Institute. A total of 998 positions were posted during the year. Personnel Officers interviewed 899 applicants, referring approximately 70% to departments for consideration. The total applicant pool was 9,035, from which 944 were hired. In addition, 213 employees transferred into new positions within the Institute.

SUSAN P. GASKELL

## CHILD CARE

The Child Care Office continues to serve the many child care needs of the MIT community by providing information and referral services. The need for child care remains constant and waiting lists for available spaces exist throughout the year. A total of 192 families were listed as having found satisfactory care. The home-based Family Day Care system had a roster of 60 providers of care on and off campus serving 200 children, mostly under three years of age. The staff also assisted a number of prospective providers of care in the process of obtaining state licensing, and continues to visit licensed homes regularly. In addition to child care services, special programs continue to flourish. The swim program served 60 pre-schoolers, and 35 children from infancy through age 6 were cared for on Commencement Day. The field trip for youngsters from 6 to 12 years had to be discontinued because of lack of qualified staff. This shortage of personnel was also being felt in the planning process for a school vacation program. Vacation care had been listed as a priority in the 1985 child care needs survey conducted on campus. This much needed service could not be provided this year since the required number of teachers could not be secured. The Child Care Office sponsored nine lunchtime seminars and six IAP activities on various topics related to children. Family Day Care providers were involved in seven hands-on programs carried out jointly with the staff of Technology Children's Center (TCC).

Technology Children's Center, the center-based child care program on campus, continues to serve over 100 children each year. Now in its fifth year, the close cooperation between the Child Care Office and TCC is being strongly felt. A considerable number of children move through the care system, starting as infants in home-based care and moving on to the Center. Parents become familiar with care options early on and visit the Center long before the children actually enter. This has created a parent-to-parent network which has helped many in the process of making child care arrangements.

LUISE FLAVIN

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## Quarter Century Club

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The MIT Quarter Century Club membership totals approximately 2000, with each member having served the Institute for more than 25 years. The annual meeting, at which new members are inducted takes place in the spring. Other annual functions include a picnic in the summer and a holiday gathering in December. The staff of the Club provides administrative and logistical support to the Institute's annual charitable campaign, the retirement dinner in June, and special functions when needed. The office administers the MIT Activities Committee (MITAC) which organizes recreational and cultural activities for the community. The Club provides services and space to a chapter of the American Association of Retired Persons Inc. (AARP). The purpose of this organization is to assist persons over 50 years of age in their social, physical, economic and intellectual needs.

An extensive travel program is organized by the manager and reviewed by a committee for the alumni, retirees, and the Institute community. Approximately 30 departures to various destinations are offered annually with many of the programs including lectures or other educational events.

The Club was founded in 1950 and became an Institute administrative department in 1978, reporting to the Vice President in the Office of the President. There are four officers and a nine member board of directors with Daniel H. Gould serving as Chairman of the board. The staff of the Club consists of Ann P. Brazier, manager, and three assistants, M. Frances Daly, Nanci Drago and Diane Betz.

JAMES J. FANDEL

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## Secondary Technical Education Project

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The Secondary Technical Education Project (STEP) was created in 1974 in response to Judge Arthur Garrity's request that Boston area colleges and businesses assist Boston Schools during the period of court ordered desegregation.

MIT is responsible, in an advisory capacity, to the students, faculty, and parents of the Mario Umana High School of Science and Technology in East Boston. This has been a difficult year for all parties associated with the school. Dr. Laval Wilson, Superintendent of Boston Public Schools, has recommended to the School Committee that the school be closed as of September, 1986. A series of community hearings were held to allow the School Committee to hear the concerns of their constituents regarding Dr. Wilson's recommendations. While the School Committee did not vote to close Mario Umana, anxieties about closing remain high.

Under the direction of the STEP Ad Hoc Committee, Director Alan Dyson now spends 80 percent of his time with the Mario Umana High School (funded through Chapter 636 Massachusetts Desegregation) and 20 percent assisting Dr. Robert Peterkin, Superintendent of Cambridge Public Schools, plan for the Cambridge Partnership for Public Education (funded through the Moses Kimball Fund).

STEP's focus in both Cambridge and Boston is to assist schools integrate computer-based technology into all phases of the curriculum, using the computer as a tool, rather than as an object of study.

The focus at Mario Umana has been a planning effort aimed at providing each student with an opportunity to become comfortable using computer-based technology. The school now has a DEC PDP 11, used primarily to teach Basic and Pasqual, a Control Data Plato Lab used to upgrade the basic skills of poorly achieving students, an Apple IIe Lab used to introduce seventh and eighth graders to applications packages and an IBM Micro Lab was installed this past year to teach students how to use business related software. The focus of this Lab is to insure that all Umana students graduate with a degree of comfort with computers.

A sub-committee of the STEP Ad Hoc has been meeting for this academic year to make a recommendation to President Gray regarding the nature of MIT's involvement with Boston area public schools.

### 1985-1986 HIGHLIGHTS

#### Mario Umana High School

Expansion of Writing/Arts Program for the Gifted and Talented.

Education Forums - Social Studies/History Based (Examples: Immigration and Juveniles and the Law).

Career Explorations for Mario Umana Students with MIT Faculty and Labs were initiated by Marcia Conroy of the MIT Museum.

#### Cambridge Public Schools

Alan Dyson, STEP Director - Assisted Planning Efforts for the Cambridge Partnership for Public Education.

Adviser to Managers of the School of the Future.

Adviser to new principal at Haggerty School.

Dr. Myron Tribus/Alan Dyson - Host series of Management Seminars for Dr. Peterkin's cabinet using W. Edward Deming's Management Philosophy.

ALAN DYSON  
DOROTHY MAC DOUGALL

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# Office of the Secretary of the Corporation

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This report summarizes the activities and the changes in composition of the Institute's governing body. The Secretary of the Corporation serves as the Corporation's Recording Officer and joint signatory with the President in the awarding of the academic degrees of the Institute. MIT's trustees rely upon the Office of the Secretary of the Corporation to provide a range of support for the members and for the Corporation committees.

## THE OFFICE OF THE SECRETARY

During last summer, following Vincent A. Fulmer's retirement, the daily tasks of the Secretary's Office were carried out by Elizabeth J. Whittaker, who was serving at the time as Assistant to the Chairman and Assistant Secretary.

Primary responsibility for the dedications program in the fall of 1985 was assumed by the President's Executive Assistant and Director of Campus Information Services, Kathryn W. Lombardi. Her contributions in the management and coordination of arrangements for the Wiesner Building and the Brown Building dedications were invaluable as was the support provided by Mary L. Morrissey, the Director of the Information Center and gifted stage manager of MIT special events. Both events were memorable MIT occasions.

Walter L. Milne, Assistant to the Chairman and to the President, also continued to provide essential help and counsel in all of the Corporation activities.

Following the October annual meeting, we restructured the Office of the Secretary. Miss Whittaker accepted a full-time position as the Assistant Secretary, senior staff member located in the new Office and responsible for the management of quarterly meetings and for all relations and services provided to Corporation members. Nancy R. Spears was appointed Assistant to the Secretary for Visiting Committees, with responsibility for logistical support, for assistance to Visiting Committee chairmen in the planning of meetings and preparation of reports, and for coordination of the annual membership changes.

The new structure has worked extremely well, considering the usual difficulties of occupying new office space and the unusual difficulties, experienced this year throughout MIT, of securing competent support staff. As our first year in office draws to a close, I must reiterate my personal gratitude to Elizabeth Whittaker. She took on the responsibility of managing the day-to-day functions beginning last summer and, during the fall, helped me to organize the new Office. She, and Nancy Spears, who joined us at mid year, are an unbeatable team. I say this especially because my predecessor, Vincent Fulmer, was a formidable one-man encyclopedia of MIT facts, and a prodigious worker, with unlimited personal energy displayed throughout his long MIT career of 34 years. His capacity for detail made for a special challenge to us as we set out not only to carry on the work, but also to establish a historical record and an information system that will improve services and will facilitate the orderly handling of an enormous amount of paper work.

Capable colleagues and effective teamwork make the difference between a good and an excellent operation, between satisfaction and pride. It is the Corporation's good fortune to be associated with competent professionals of the calibre of Miss Whittaker and Ms. Spears.

## CORPORATION MEMBERSHIP

At the year's end the total of 98 members of the Corporation included 44 Term Members, 23 Life Members, 8 Ex Officio Members, and 23 Life Members Emeriti. This compared with 99 members at the close of the previous year.

Effective June 30, 1986, the following four members completed their designated terms of service:

Harl P. Aldrich, Jr. '47  
Elisabeth M. Drake '58  
Barbara M. Johnston '80  
George M. Keller '48

Their participation in the work of the Corporation has been deeply appreciated. Fortunately, they will continue their association with the Institute as alumni and as members of the Corporation and Institute committees so that MIT will still benefit from their knowledge and expertise.

Effective July 1, 1986, eight new members were elected to five-year terms:

E. Milton Bevington '49  
Ernest U. Buckman '46  
Alex W. Dreyfoos, Jr. '54  
Joe F. Moore '52  
DuWayne J. Peterson, Jr. '55  
Charles H. Spaulding '51  
Sarah A. L. Tabler '85  
Morris Tanenbaum

These new members bring a wide diversity of backgrounds and interests to the Corporation and will add in significant ways to the effectiveness of its work as the Institute moves into the next decade. We are indebted to members of the Corporation Membership Committee, chaired by Dr. David S. Saxon, and including Messrs. Gray, Johnson, Kane, Kerr, Leventhal, and Thorn; to the Screening Committee, chaired by Dr. Heidi R. Wyle; and to the staff of the Alumni Association for providing us with such outstanding candidates for election to the Corporation.

E. Milton Bevington '49 completed his term of service as President of the Alumni Association and was succeeded by Joseph G. Gavin, Jr. '41. The Institute is indeed fortunate to have such dedicated and competent alumni available to serve in this key position.

John H. Lawson, Commissioner of Education for the Commonwealth of Massachusetts and, as such, an ex officio member of the Corporation, retired from that position on April 30, 1986, and was succeeded on June 1, 1986, by Harold Reynolds, Jr.

Under Section 5.1 of the Bylaws, Frank R. Milliken '34, at his own request, was transferred to Life Member Emeritus, effective July 1, 1986. At the June meeting of the Corporation, Chairman David S. Saxon praised Mr. Milliken's 24 years of distinguished service to the Corporation, and his comments were entered into the records of the meeting. The members of the Corporation warmly applauded Mr. Milliken in absentia.

Memorial resolutions honoring five Life Members Emeriti who died in the past year were adopted by the Corporation and made part of the permanent records of the Institute. Those honored were:

Lloyd D. Brace  
Donald F. Carpenter '22  
Gwilym A. Price  
Robert A. Lovett  
John J. Wilson '29

Their combined terms of service total a remarkable 166 years. These members will all be greatly missed by their colleagues, but their contributions to the work of the Corporation and the Institute will long endure. I would like to add here a special word on the passing of John J. Wilson who held the Office of Secretary of the Corporation from 1959 to 1979. John Wilson was a model MIT trustee and Officer of the Corporation. His wisdom and dedication to his alma mater were matched only by a keen and discriminating sense of propriety and protocol when it came to the duties of the Corporate Secretary. I will certainly miss his guidance and his support.

#### CORPORATION COMMITTEES

##### Advisory Committee on Shareholder Responsibility

Thanks are due again to the members of the Advisory Committee on Shareholder Responsibility (ACSR), under the chairmanship of D. Reid Weedon, Jr., for their continuing assistance to the Executive Committee of the Corporation and for their thorough review, at the request of the Executive Committee, of MIT's guidelines for assessing corporate proxy questions related to South Africa. As a result of its review, the ACSR recommended new guidelines which were subsequently adopted by the Executive Committee and endorsed by the Corporation. Walter L. Milne, Assistant to the President and to the Chairman of the Corporation, and Ronald P. Suduiko, Special Assistant in the Office of the Chairman, once again provided valuable staff support to the Advisory Committee.

##### Corporation Joint Advisory Committee on Institute-Wide Affairs

The Corporation Joint Advisory Committee on Institute-Wide Affairs (CJAC), led by Chairman Emily V. Wade, had a very active spring as the result of a charge by the Executive Committee to do what CJAC could to improve communication among MIT's varied constituencies.

CJAC met by itself and with the members of an ad hoc campus Coalition Against Apartheid (CAA) to consider what role CJAC might play in the campus concern over MIT's investments in U. S. companies that have operations in South Africa. The Secretary of the Corporation invited members of the Corporation Executive Committee and members of the CAA to a meeting to give the CAA members a chance to talk directly to the Executive Committee.

CJAC plans to meet during the summer to consider further its role in campus issues.

#### CORPORATION VISITING COMMITTEES

Last September Alice Tripp was hired on an interim basis to manage the logistics of the Visiting Committee meetings until a permanent staff could be appointed. Mrs. Tripp did an excellent job of coordinating the scheduling and providing support for the fall Visiting Committee meetings. In January, Nancy R. Spears took over as Assistant to the Secretary for Visiting Committees.

This year the following committees met:

<u>Department/School</u>	<u>Date</u>	<u>Chairman</u>
School of Architecture and Planning	October 17-18	Norman B. Leventhal
Athletics	October 23-24	Howard W. Johnson (for Irénée du Pont, Jr.)
Chemistry	November 13-14	Paul M. Cook
Linguistics and Philosophy	November 20-21	Edward T. Thompson
Mechanical Engineering	November 5-6	E. R. Kane
Sloan School of Management	December 4-5	T. A. Wilson
Materials Science and Engineering	February 11-12	Robert L. Mitchell
Aeronautics and Astronautics	March 5-6	Frank S. Wyle
Nuclear Engineering	March 12-13	Edward O. Vetter
Earth Sciences	March 19-20	Breene M. Kerr
Civil Engineering	April 2-3	Harl P. Aldrich
Biology	May 22-23	David I. Kosowsky
Libraries	May 28-29	Rita A. O'Brien
Whitaker College	June 11-12	W. Gerald Austen

Timely reporting continues to be emphasized and so far has been very successful. Oral reports were heard from all but four of the committees that met this year, and the four remaining reports are scheduled for the October Corporation meeting. Eight out of 14 written reports have been submitted, thanks to prompt work by committee chairmen and continued reinforcement by Dr. Saxon.

This was the first year in which Professor John M. Deutch participated as Provost. He made vital contributions to the committee meetings and to our evaluation of the whole process. The Provost also participates with the Officers of the Corporation in a comprehensive annual review and restructuring of the Visiting Committee membership. This year 467 members served in 26 Visiting Committees.

This spring we decided on two procedural changes:

- New presidential appointments will serve a four-year term in keeping with the 18- to 24-month meeting cycle, thus allowing each member to attend two meetings during his or her term; and
- Chairmen will now serve five-year terms in order to tap the expertise and perspective of new Corporation members and to ease the burden on those who have served many years.



Several on-going goals include a limit of membership to 15 for most committees and a continued press for increase in minority and female representation.

The Corporation Visiting Committees lost two faithful friends this year in the deaths of Wayne J. Holman, Jr. of the Sloan School Visiting Committee and Howard Vollum of the Electrical Engineering and Computer Science Visiting Committee. We were also grieved by the death of MIT alumnus Dr. Ronald L. McNair who died in the Challenger tragedy in January. Dr. McNair was to attend his first meeting of the Aeronautics and Astronautics Visiting Committee in March.

#### MEETINGS OF THE CORPORATION

The Corporation met, as scheduled, on the first Fridays of October, December, and March, and on Commencement Day, Monday, June 2, 1986.

The Annual Meeting in October was a full day's meeting with a working lunch. Following the business session, the Corporation devoted the afternoon to a discussion of the forthcoming Campaign for MIT. The meeting concluded with a formal request on the part of the Corporation asking that the Officers report at an early date in 1986 on the scope and scale, the duration, and the operational characteristics of the Campaign for MIT.

On the day preceding the Annual Meeting, Dr. Saxon presided over an orientation session for new members. This is the third year in which this program has been offered to new members. It is now an established part of our Annual Meeting events.

At the December meeting, the Corporation heard a report from Professor Margaret L. A. MacVicar, MIT's first Dean for Undergraduate Education, on the organizational and programmatic changes taking place in undergraduate program.

At the March meeting once again there was a full discussion on the Campaign, and agreement was reached with respect to the broad outlines. The Campaign for MIT will be announced in the spring of 1987. It will be a five-year effort, 1987-92, with a minimum goal of \$500 million. Core needs will be emphasized with program priorities tied closely to them. The Nucleus Fund is now under way. One major goal of the Campaign will be to effect a major increase in the annual gift flow to a range of \$100 million.

Throughout the year members of the Corporation expressed a lively interest in hearing the President report on issues related to South Africa and to the interest expressed in this and other academic communities to divest the university holdings of stock of U. S. companies that do business in South Africa. In the March meeting the Executive Committee presented a policy statement based on the decision not to divest MIT's holdings. Following discussion, the Corporation voted to endorse the Executive Committee statement.

Following an early morning meeting on June 2, Corporation members joined the academic procession and marched to Killian Court for the Commencement exercises. In addition to Dr. Gray and Dr. Saxon, the Corporation contingent on stage that morning included former MIT Presidents Killian, Stratton, Johnson, and Wiesner. It was the dampest Commencement in recent memory but nonetheless a happy occasion for the graduates and their guests, punctuated by the Commencement address of William R. Hewlett '36.

#### BUILDING DEDICATIONS

The Corporation was responsible for two building dedications in the past year. Each was a noteworthy event.

The first was the dedication on October 2, 1985, of the Jerome B. and Laya W. Wiesner Building housing the arts and media technology facilities. In addition to the dedication ceremony, there were three days of celebratory events including a banquet and two-day-long symposia. The dedication of the building marked the completion of a six-year fundraising effort, spearheaded by the Council for the Arts; its Chairman, Dr. Wiesner; and Professor Nicholas P. Negroponte, who is the Director of the new Center for Media Technology.

The Corporation at its meeting on June 3, 1985, had adopted Resolutions naming the building in honor of the Wiesners, in recognition of their dedication to the Institute and their sustained advocacy of the arts and communications technologies and of Dr. Wiesner's central role in securing funds for the construction of the building. The architect was I. M. Pei '40, a former member of the MIT Corporation who participated in several of the events surrounding the dedication.

The formal dedicatory program included an electronic unveiling of plaques honoring individuals, corporations, and foundations from the United States, Europe, and Japan whose donations made possible the construction of the building. It was a memorable occasion, with outstanding attendance from every part of the Institute community.

The second building dedication took place on December 6, 1985, when the newly renovated building housing the Microsystems Research Center was named in honor of Gordon Stanley Brown '31, Institute Professor Emeritus and MIT's sixth Dean of Engineering. On the recommendation of the Executive Committee, the Corporation at its meeting on October 4, 1985, had adopted formal Resolutions naming the building in honor of Dean Brown. Events surrounding the dedication included a symposium entitled "Diamonds in the Sand." Dean Brown and members of his family were guests of honor at the Corporation luncheon preceding the dedicatory ceremony. It was a day of warm feeling and nostalgia, culminating in the cutting of a cake upon which was reproduced a famous chart created years ago by Dean Brown to illustrate his vision of how interdisciplinary research centers could energize education.

#### POST SCRIPT

Following past practice, this has been a rather detailed report from the new Secretary of the Corporation. The year went by in a breathless pace and there are many people whose contributions and assistance were vital to the success of our work. On behalf of the Corporation I wish to thank especially the 370 men and women who joined our members in the work of the Corporation's 26 visiting committees. Fourteen of these committees met on campus this year. In my brief experience on this job, I believe that the contribution these committees make both to the intellectual life and to the governance of this institution is crucial and unique in the field of higher education.

CONSTANTINE B. SIMONIDES

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## Committee on the Visual Arts

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A presidentially appointed group composed of members of the faculty, administration and student body, the Committee on the Visual Arts (CVA) oversees policy for an ambitious program in the visual arts which is administered by a professional staff. The CVA is charged with a broad spectrum of responsibilities: to foster and present, through its nationally recognized exhibition program housed in the three galleries of the List Visual Arts Center the most challenging contemporary art and design; to provide the MIT community and general public with educational activities which increase visual literacy and explain how the visual arts reflect the ideas and conditions which define contemporary society; to enhance the quality of the Institute's visual environment and to encourage daily familiarity with museum-quality works of art through three publicly sited collections of contemporary art in all mediums; and to contribute to the cultural vitality and variety of the region.

The CVA met four times during the 1985-86 academic year. The focus of its deliberations was the increased programmatic responsibilities, budgetary constraints and public visibility associated with the operation of the List Visual Arts Center. It was agreed that the program, as presently developed, staffed and funded, was overly ambitious; consequently, a more reasonably-scaled program for 1986-87 was proposed and accepted. During this period, the membership, concurrent with the Provost's Office, will study the growth of MIT's art programs, the relationship of the exhibition and acquisition programs to academic departments, and avenues for future support. Eight proposals for 1986-87 initiatives were prepared, reviewed and presented to external agencies and foundations.

### EXHIBITION PROGRAM

The 1985-86 season, comprising 12 exhibitions, was the first to occur entirely within the three new galleries of the List Visual Arts Center. Generally the exhibition spaces were programmed independently, with four major exhibitions installed in the Hayden Gallery, four residencies and one architectural exhibition in the Reference Gallery and two exhibitions in the Bakalar Sculpture Gallery. The final exhibition was installed in all three spaces simultaneously. Programs were reviewed in the public press with prominent coverage received in the Boston Globe, Phoenix, Art New England, The New York Times, AIA Journal, and other publications. Attendance is estimated at approximately 15,000.

### 1985-86 Exhibition Schedule

List and Stratton Student Loan Collections, Hayden Gallery, August 30 - September 17, 1985. The popular annual exhibition and lottery of approximately 280 contemporary prints and artist-designed posters, including significant recent additions by, for example, Nancy Graves, Neil Welliver and Mel Bochner.

Private Works by Public Artists: Scott Burton, Richard Fleischner and Kenneth Noland, Hayden Gallery, October 1 - November 24, 1985. On the occasion of the dedication of the Wiesner Building, works by the three artists who collaborated with architects I.M. Pei & Partners allowed visitors to compare art produced in the privacy of the artists' studios with work conceived for a more public and functional orientation.

Ping Chong: KINDNESS, Reference Gallery, September 9 - October 27, 1985. In conjunction with his residency on the topic of cultural displacement the New York-based performance artist designed a two-tiered, full gallery installation juxtaposing a dark mysterious pool and sanctuary surmounted by a stark white and empty late 20th century space. (Supported in part by the Massachusetts Council on the Arts and Humanities)

Henry Moore: Figures and Forms, Bakalar Sculpture Gallery, October 4 - January 5, 1986. The second in a series of teaching exhibitions charting the development of 20th century sculpture. Guest-curated by Jeanne Wassermann, the exhibition investigated the fertile relationship between the artist's quasi-abstractions and sources in the figural world. Brochure published. (Supported in part by the National Endowment for the Arts) Exhibition coincided with the installation on Wiesner Building plaza of Moore's major bronze Reclining Figure, 1963, a gift of Albert and Vera List in honor of her brother Samuel Glaser, MIT '25.

Richard Kriesche: CULTECH, Reference Gallery, November 4 - December 29, 1986. Kriesche, an Austrian artist whose films, videos and publications consistently focus on the relationship of new technologies to the social conditions they both convey and create, investigated the effects of electronic information systems on the creation of political, social and, by implication, psychological boundaries. His installation and performance (videotaped for subsequent presentation in the gallery) brought together a galaxy of small blue ceiling lights, a navigational chart and computerized video projection onto a pool of milk. (Supported in part by the Massachusetts Council on the Arts and Humanities)

Nude, Naked, Stripped, Hayden Gallery, December 13 - February 4, 1986. Contemporary paintings, sculpture and photography, by 18 artists who represented a variety of different current attitudes toward the body without clothes as an arena for exploring personal and universal human identity. An installation on the body of the future by the artists' collaborative TODT was supported by the Council on the Arts at MIT. 80-page illustrated catalogue published.

Marina Abramovic and Ulay: MODUS VIVENDI, Reference Gallery, January 6 - February 9, 1986. The two European artists who have collaborated in performance, photography, film and video since 1973 showed a series of gigantic Polaroid photographs investigating male and female archetypes. In addition they produced and screened "Terminal Garden," the third in their projected series of five videotapes to be made on each continent in response to the particularities of place and culture. (Residency supported in part by the Massachusetts Council on the Arts and Humanities; videotape supported in part by the Council on the Arts at MIT)

Alexander Calder: Artist as Engineer, Bakalar Sculpture Gallery, January 31 - April 13, 1986. Curated by Professor Joan Marter from Rutgers University, this third in the series of teaching exhibitions in 20th century sculpture illustrated Calder's early interest and training in different systems of kinetics and his continuing applications of these principles in his later mobiles. Brochure published. (Supported in part by the National Endowment for the Arts)

Alvar Aalto: Furniture and Glass, Hayden Gallery, February 28 - April 13, 1986. Organized by the Museum of Modern Art, this circulating exhibition presented the full range of the Finnish architect's furniture, from the early experimental tubular steel pieces through all the inventive iterations in bent wood, together with the free-form glass vases and bowls designed with his wife Aino. (Supported in part by the School of Architecture)

Alvaro Siza: Buildings and Projects, Reference Gallery, February 28 - April 6, 1986. The prize-winning Portuguese architect, well-known in Europe but shown here for the first time in the United States, designed the exhibition installation of his sketches, drawings, models and photographs, thus providing the viewer with the three-dimensional experience of his spatial problem solving. Brochure published, with first English language text on the architect by Peter Testa, a recent MIT School of Architecture graduate. (Sponsored in part by the Calouste Gulbenkian Foundation)

Mabou Mines: IMAGINATION DEAD IMAGINE, Reference Gallery, April 13 - 27, 1986. In conjunction with the residency of Linda Hartinian and Ruth Malaczek of this New York-based experimental theater troupe, and the performance of their short theater piece based on the Beckett text, a set involving four multiplex 360-degree holographs rotating above a bier-like sculpture of cast detritus was installed. (Supported in part by the Massachusetts Council on the Arts and Humanities)

Natural Forms and Forces: Abstract Images in Contemporary American Sculpture, Hayden, Reference and Bakalar Galleries, May 9 - June 29, 1986. This exhibition of sculpture and drawings brought together work by Lynda Benglis, John Duff, Nancy Graves, Ellsworth Kelly, John Newman, Martin Puryear, Alan Saret, Richard Serra and Alan Stone, whose point of departure, despite disparate materials, is a deeply internalized response to the forms and forces of the natural world. A historical context was provided by selected earlier work by Eva Hesse, Michael Lekakis, Theodore Roszak, Robert Smithson and Ruth Vollmer. This component of the exhibition, curated by Douglas Dreishpoon, was installed in the Bakalar Gallery. 68-page illustrated catalogue produced. (Co-sponsored, supported by and exhibited jointly at Bank of Boston; additional support provided by the National Endowment for the Arts)

## EDUCATIONAL PROGRAMS

Exhibition-related educational activities took a variety of forms and foci in order to involve the varying backgrounds and interests of the members of the immediate MIT and larger regional audiences.

### Informational Texts

Artists and Architects Collaborate: Designing the Wiesner Building (96 pages with 12 page photographic supplement) a documentation of the pioneering collaboration between Scott Burton, Richard Fleischner and Kenneth Noland with I.M. Pei, with interviews involving all protagonists and an essay by Robert Campbell, Boston Globe Architecture Critic and Jeffrey Cruikshank, Senior Editor of Publications, Harvard Business School, was published for the dedication of the Wiesner Building on October 2, 1985. (Publication supported by the National Endowment for the Arts and the Council for the Arts at MIT)

The illustrated brochure describing the CVA history and current philosophy and activities was revised and reissued to reflect the expanded programs in the List Visual Arts Center.

All exhibitions were accompanied by a catalogue, brochure and/or wall text prepared by the curatorial staff to provide viewers with an introduction to and context for the work on view. Statements by each of the artists in Nude, Naked, Stripped, discussing their aims, attitudes and processes, were presented alongside their works.

### Talks, Tours, and Lectures

Gallery talks and tours of the collection were arranged for numerous MIT groups, such as incoming freshmen and alumni, and outside organizations; Trustees of the San Francisco Museum of Art, members of the Currier Art Gallery, and the local chapter of the Industrial Design Society of America, for example.

In addition, lectures or special events were arranged for each exhibition. Ann Garrould of the Henry Moore Foundation presented a slide lecture "Henry Moore: His Art and Environment" in the Bartos Theatre. Seven interdisciplinary lunch-time discussions involving MIT faculty and outside authorities accompanied Nude, Naked, Stripped, on topics such as "The Psychology of Nakedness," and "The Anthropology of Clothes."

J. Stewart Johnson, curator of Alvar Aalto: Furniture and Glass, lectured on the development of Aalto's unique aesthetic; exhibiting Portuguese architect Alvaro Siza presented a slide lecture on his built work and held studios in the Department of Architecture. In conjunction with Natural Forms and Forces, CVA Curator Katy Kline led a public gallery talk, and the film Masters of Modern Sculpture was screened. All events were free and open to the MIT community and the public.

### Artists in Residence

The various projects and endeavors of the four resident artists or artist-teams were anchored in the Reference Gallery, a hybrid of laboratory, staging area, and classroom. The CVA staff, in collaboration with the artists, devised a gamut of educational activities appropriate to each residency project. Ping Chong lectured on his work in multi-media performance and participated in a series of discussions on the artist and ethnicity and on cultural biases in cognition, technology and perception. In addition, Jamake Highwater, an authority on Native American culture, lectured on "The Primal Mind." On his arrival at MIT, Austrian multi-media artist Richard Kriesche discussed his recent projects. At the conclusion of his six week project, he presented a performance generated from his research and discussions with various MIT faculty. Collaborating artists Ulay & Marina Abramovic presented an evening program of discussion, slides and video to introduce the community to their varied activities. While in residence they produced a videotape in their ongoing "Continental Video Series," using the Media Lab's Terminal Garden as a set, and a computer-synthesized voice soundtrack, developed with a graduate student. Members of the experimental theatre company Mabou Mines presented fifteen full-house performances of their holographic theatre work Imagination Dead Imagine, and lectured on the uses of holography in the theatre, taught a MIT Dramashop directing seminar, and produced a new hologram with a student from the Spatial Imaging Group.

### ACQUISITIONS

The following works were acquired through either gift or purchase during the 1985-86 academic year:

#### Permanent Collection

Henry Moore, RECLINING FIGURE, 1963, bronze. Gift of the Albert and Vera List Family Collection.

Donald Sultan, BLACK LEMONS, November 29, 1984, aquatint. Gift of the Albert and Vera List Family Collection.

Donald Sultan, BLACK LEMON, December 1, 1984, aquatint. Gift of the Albert and Vera List Family Collection.

Jacques Lipchitz, SONG OF SONGS, c. 1946, bronze. Gift of Josephine W. and Ralph Pomerance in honor of Jerome Wiesner.

Manuel Alvarez Bravo, three black and white photographs (completes a portfolio given in 1984-1985). Gift of Bruce M. Male.

Jonathan Imber, UNTITLED (Deborah Looking in the Mirror from Back), 1984, pastel on paper. Purchase, Harry Portnoy Retirement Fund.

Maggi Brown, A FINE LINE, 1985, oil on paper. Purchase, Harry Portnoy Retirement Fund.

Sean Scully, THE FALL, 1984, etching and aquatint. Purchase, Harry Portnoy Retirement Fund.

Susan Belton, WHERE'S THE ENTRANCE, 1983, acrylic on paper. Purchase, Harry Portnoy Retirement Fund.

Denny Moers, DIGRESSION OF AN ANGEL #1, 1985, photographic monoprint. Purchase, Harry Portnoy Retirement Fund.

Ruth Bauer, SALEM HARBOR, 1985, watercolor. Purchase, Harry Portnoy Retirement Fund.

Sigmund Abeles, THE ARTIST'S MOTHER, n.d., etching. Purchase, Harry Portnoy Retirement Fund.

Richard Estes, SALZBURGH CATHEDRAL, 1982, silkscreen. Gift of the Albert and Vera List Family Collection.

Carroll Dunham, COLOR MESSAGE A, 1985-86, color lithograph. Purchase, Harry Portnoy Retirement Fund.

#### List Student Loan Collection

Susan Crile, UNTITLED, n.d., silkscreen. Gift of the Albert and Vera List Collection.

Peter Plagens, UNTITLED, 1983, silkscreen. Gift of the Albert and Vera List Collection.

Rosalyn Richards, EARTHQUAKE, 1984, woodcut. Gift of the Albert and Vera List Collection.

#### Catherine N. Stratton Student Loan Collection

Nancy Graves, IMAGINATION DEAD IMAGINE, 1985, signed poster. Gift of Mabou Mines Development Foundation, Inc.

#### Ronald A. Kurtz Student Loan Collection

Berenice Abbott, 50 black and white photographs, various dates. Gift of Ronald A. Kurtz.

#### EXTENDED LOANS TO THE COLLECTION

(See previous reports.)

#### LOANS FROM THE PERMANENT COLLECTION TO OTHER INSTITUTIONS

Joyce Kozloff, THREE FACADES, 1973 and MITLA, 1974, to the Boston University Art Gallery, Boston, for the exhibition Joyce Kozloff: Visionary Ornament, February - April 1986 and subsequent tour to University of New Mexico, Albuquerque, NM; College of Wooster, OH; Hunter Museum of Art, Chattanooga, TN; and Moore College of Art, Philadelphia, PA.

Thomas Cole, LANDSCAPE WITH INDIANS, HUDSON HIGHLANDS, c. 1826, to the Nassau County Museum of Art, Roslyn, NY for the exhibition American Artists Abroad: The European Experience in the 19th Century, June - September 1985.

#### CONSERVATION

Restorative work was performed by Steve Tatti, conservator, on Henry Moore's RECLINING FIGURE 1963, Beverly Pepper's TRINITY (formerly DUNES I), Gary Wiley's INVADERS and on Michael Heizer's GUENNETTE which is on loan to MIT from the Metropolitan Museum of Art, New York.

The Center for Conservation Studies, Harvard University Art Museums, treated two paintings: Richard Smith's REVOLVAL I and Adja Yunkers' ELEGY FOR A DEAD PAINTER (Homage to Mark Rothko).

Alexander Calder's MOBILE was re-painted in preparation for inclusion in the exhibition Alexander Calder: Artist as Engineer, held in the Bakalar Sculpture Gallery, January 31 - April 13, 1986.

Several works were framed or re-framed by Old Cambridge Co., Cambridge.

KATHY HALBREICH  
BORIS MAGASANIK

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## Council for the Arts

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Continued transition, assessment, and evaluation have been the themes of this, the fifteenth, year of the Council's existence. Completion and dedication of the new Laya and Jerome B. Wiesner Building for Arts and Media Technology marked the realization of a dream the Council had worked toward almost since its founding and left Council members asking, "Now what?" The Deans of the Schools of Architecture and Planning (John de Monchaux) and Humanities and Social Sciences (Ann Friedlaender) assumed ex officio positions on the Council's Executive Committee in order to strengthen ties between the Council and MIT's academic programs. Deborah Hoover, Executive Director of the Council for four years, and a staff member for a total of seven, resigned and was replaced by Helvi McClelland. And, at the close of the year, Provost John Deutch announced the intended formation of a faculty-based committee to review, during the 1986-87 academic year, all of MIT's academic, extracurricular, and administrative programs in the visual and performing arts.

### Grants Program

The Grants Program continued to be the Council's most visible activity. This year, the Grants Committee, chaired by Bradford M. Endicott '49, received and reviewed 76 proposals from students, student groups, faculty, and staff, requesting a total of \$165,531. Of these, 57 projects (75% of those submitted) were awarded \$74,960 (45% of the amount requested). Anticipated matching funds for these projects equalled \$308,375 (\$185,440 in cash, and \$122,935 worth of in-kind contributions). In addition, Council staff made five Officer's Grants totaling \$1,073.55. A detailed report from the Grants Committee is available.

Clearly, the importance of the Grants Program lies in its making available funds and expertise to support new initiatives in the arts. This year, as in years past, these initiatives have ranged from the fledgling ideas and efforts of individuals with no substantial prior arts experience to highly sophisticated projects undertaken by professional artists affiliated with MIT as fellows, staff, or faculty. Some funded projects have been intimately connected with established academic programs; others have been purely extracurricular and individual.

This year, in order to begin systematically to collect data that will enable the Grants Committee to evaluate the success of various types of projects actually funded, Council staff revised and began enforcing a requirement that grantees submit final descriptive reports and financial statements upon completion of their projects. The Grants Committee also convened an extra, special, year-end meeting to begin to assess its award guidelines and criteria and the overall success of the program.

### Publications

Six issues of the Council's calendar/newsletter, The Arts at MIT, were produced and distributed to a mailing list of 8,500 alumni, friends, faculty, staff, student groups, and other individuals. This year, the newsletter included a special series of three articles written by Richard MacMillan about MIT alumni who have made careers in the arts.

The Arts Hotline, a weekly telephone announcement of all arts events taking place at MIT was maintained for its second year.

Alison Shafer produced the 5th edition of MIT Arts in the News, a compilation of news and feature articles about MIT artists and arts activities originally published in local, national and international newspapers and magazines. Over twenty thousand copies were distributed in the February 12 issue of TECH TALK, fifteen hundred copies were given to the Admissions Office, and one thousand were distributed to arts and humanities faculty and organizations.

### Programmatic and Technical Assistance

Council staff have continued to provide advice, ideas, research, and administrative support regarding the development of arts projects or organizations to MIT students, faculty and staff. This year, Alison Shafer worked with Andrew M. Eisenmann '75, Staff Assistant for Campus Activities in the Student Affairs Office, to structure, organize, and lead an Ad Hoc Committee on the Wiesner Student Art Gallery, the purpose of which is to develop exhibition standards and procedures and financial resources for the Gallery.

Members of MIT's support staff convened a seminar during the Institute's Independent Activities Period (IAP) entitled, "The Artist Behind the Desk," to provide an opportunity for some of the many artists on

staff at MIT to meet one another and to explore ways in which they might support each other as artists. Alison Shafer attended two of their meetings to provide information on the arts at MIT, the Council, and the Council's Grants Program.

Council staff worked with Council member Eugene Schnell '44, Richard Bader, owner of Boston's Wilbur Theater, and Robert N. Scanlan '70, Director of MIT's Dramashop, to sponsor a visit with MIT students by playwright David Mamet, who was in Boston for a production of his Glengarry Glen Ross. Scanlan called Mamet's visit "one of the most exciting guest lectures we have had in drama in many years. What he gave us was, in essence, a master class in acting, directing and the art of the theater."

#### Visiting Artists Program

Due to delays in the completion of the Villers Experimental Media Facility in the new Wiesner Building, performances of a contemporary version of Flaubert's The Temptation of St. Anthony by The Wooster Group under the direction of Peter Sellars were re-scheduled to February, 1987. Work on those performances has been funded in part by a grant obtained by the Council from the Massachusetts Council on the Arts and Humanities.

Media artist Richard Zvonar '67 completed a collaborative residency with Ricky Leacock, Professor of Film in MIT's Media Laboratory. That residency was funded in part by the National Endowment for the Arts.

In a meeting with Helvi McClelland and Richard MacMillan, Susan Hartnett, Director of the Contemporary Arts Program of the Massachusetts Council on the Arts and Humanities, expressed enthusiasm for the Visiting Artists Program and encouraged the Council to develop a clear and intellectually consistent rationale connecting its various requests for funding.

#### Abramowitz Memorial Concert

Through the support of the William L. Abramowitz Lecture Fund, the Council commissioned MIT Professor of Music John Harbison to write a piece of music of any length and intent that could be performed by an MIT ensemble, and to perform that piece in a program whose other works would provide a context suggesting Mr. Harbison's affinities, inheritances, and secret passions. The piece, Music for Eighteen Winds, was performed by the MIT Chamber Players under Mr. Harbison's direction in Kresge Auditorium on April 18. Richard MacMillan produced the concert, and Council members Kay Stratton and Elsa Sonnabend hosted a post-concert reception for Mr. Harbison, the players, and guests of the Abramowitz family.

#### Boston Museum of Fine Arts University Membership Program

For the sixth year, the Council funded MIT's participation in the MFA's University Membership Program which allows all MIT students to attend any Museum exhibit or event at no charge and as frequently as they wish. This year's participation was made possible by special contributions from Bernard G. Palitz '47 and Bradford M. Endicott '49. Figures for the number of visits by MIT students this year are not available; in past years, the Museum has recorded 9,500-13,500 annually.

As in years past, Alison Shafer and two student volunteers assisted the MFA with the planning of The Event, an annual open house and evening of student art and performances held at the Museum. This year, MIT was represented by The MIT Logarithms, Tau Beta Pi and the Musical Sidewalk, and a piano recital by undergraduate and graduate students.

#### Endowed Prizes and Awards

Walter Rosenblith, Council member and Institute Professor Emeritus, served as Acting Chairman (substituting for Roy Lamson) of the Student Art Awards Committee. The Laya and Jerome B. Wiesner Student Art Award was presented to Daniel Turner '87 (Course XXI) for his contributions to the literary life of MIT. The Louis Sudler Prize in the Arts was awarded to graduating senior Lauren Singer (Course VI) for her outstanding achievements in the dramatic arts. The Gyorgy Kepes Fellowship Prize was not awarded during FY86.

#### Development Activities

Most of the Council's funds for both its operating expenses and Grants Program continued to come from Council members and other donors. This year, 62 members made contributions averaging \$3,164 each, an amount 13 percent higher than last year. Fifty-four other donors contributed an average of \$445 each.

As the Council's budget has increased over the years, required funds have begun to exceed the amount that can reasonably be expected to come from a fixed number of individual gifts. The Council's Development Committee, organized by Richard MacMillan and chaired by Gregory Smith '30, met twice this year to conceive new fundraising strategies.



Two new fundraising vehicles were initiated on a small, experimental scale. Council member Bernard G. Palitz '47 hosted a luncheon in New York at the Carlyle Hotel at which potential donors heard presentations made by four MIT arts faculty about projects in the arts at MIT that need funding. That effort resulted in a gift of \$5,000 to Professor Heather Lechtman in support of her summer seminar in materials science applications to art conservation research.

Council member DeeDee Pharr made arrangements for New York area members and donors to attend Council member Zoe Caldwell's one-woman show, Lillian, at the Barrymore Theater and to have dinner with Ms. Caldwell afterward at Pierre Au Tunnel. Tickets for the event were sold at \$100 per person, and the proceeds were added to the Council's operating funds.

The sad occasion of Council member Roy Lamson's death prompted Council members Kay Stratton and Vincent A. Fulmer '53G, and Associate Provost Jay Keyser to establish the Roy Lamson Memorial Fund for Music at MIT. Dr. Keyser made the initial contribution by donating fees received by the Intermission Trio, an MIT faculty jazz ensemble founded by Professor Lamson in 1964. The Fund will be used by the Grants Committee to support exceptional music projects.

#### Gifts of Works of Art

Council members have regularly contributed works of art to the MIT Permanent Collection, the List Student Loan Program, and the Catherine N. Stratton Student Loan Collection. This year, MIT's Committee on the Visual Arts established the Ronald A. Kurtz ('54) Student Loan Collection with a gift from Mr. Kurtz of fifty black and white photographs by Berenice Abbott.

Three of this year's exhibits at the MIT Museum were made possible by Council members. "Visions of the Twentieth Century" (Berenice Abbott photographs) and "Ansel Adams: Photographs," were comprised of prints from the collection of Ronald A. Kurtz '54. And, "Yulla: Images of Infinity," an exhibition of photomontages by Council member Yulla Lipchitz, was underwritten by a gift from another Council member. Mrs. Lipchitz was present both for the opening of the show and at a later date when she met and spoke with students.

#### Annual Meeting/Dedication

The Fourteenth Annual Meeting of the Council took place on October 1, in connection with the dedication of the new Jerome B. and Laya W. Wiesner Building for arts and media technology. Albert and (Council member) Vera List presented MIT with Henry Moore's "Reclining Figure, 1963." A dinner for Council members and other invited guests celebrated the Wiesner Building, the artist-architect collaboration, and the Council's important role in bringing it all about.

Council member Harold E. (Doc) Edgerton '27 was awarded this year's McDermott Award. In return, he captivated and delighted his audience with a slide presentation and talk about his work with strobe photography. (Doc chose to have a portion of the award honorarium used to purchase 150 copies of his book, Electronic Flash, Strobe, which he signed and distributed to students from the Council office later in the year. Students began lining up almost 2 hours in advance of the advertised time, and the 150 books were taken within 45 minutes!)

After the Annual Meeting, many Council members remained at MIT to attend the formal dedication ceremonies and symposia on media arts, sciences, and technologies held on the following two days. It was a time of great excitement and enthusiasm.

#### Membership

At the end of the year, Council membership stands at 89.

Two founding members died during the year, Max Wasserman on January 1, and Roy Lamson on May 3. One member, Annette Berger, resigned from the Council.

Of the fifty-nine members whose terms expired this year, fifty-two were renewed. A list of expirations and renewals is available.

The Executive Committee voted to extend membership status to the Council's outgoing Executive Director, Deborah Hoover, upon her resignation in October. In addition, three new members accepted three-year terms to begin on July 1, 1986. These are Ronald Cordover '64, Haskell Gordon '38, and Alan Katzenstein '42.

The Council's need to raise ever increasing amounts of money to cover its operating expenses and programs, coupled with the expectation that most of its funds will come from the contributions of members, makes clear that the Council must have among its membership a sufficient number of individuals able and willing to make significant gifts. In the past, prospective members have been selected, in

large part, according to demonstrated scholarship, creativity, and distinguished service in various arts disciplines. This year, Council members and staff began discussing ways in which necessary alterations in membership criteria and responsibilities might be made in order to insure that both financial and artistic needs are met.

#### Personnel

Following the resignation of Deborah Hoover, Helvi McClelland joined the staff as Executive Director. Richard MacMillan was promoted to Associate Director. Alison Shafer continued as the Council's Program Officer. Administrative Secretary, Ann Derby, joined the staff in January.

HELVI McCLELLAND

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## Vice President for Financial Operations

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Fiscal 1986 is the third consecutive year that we have had a modest surplus. We are also projecting a small surplus for fiscal 1987 if conditions remain favorable.

Despite the favorable financial results of the last few years, we continue to face critical financial issues that require increased endowment if they are to be resolved. Three of these major issues are the following:

- spending most unrestricted gifts, grants and bequests for current operations rather than to increase endowment;
- reliance on sponsored research for over two thirds of operating revenues and the relatively small portion of unrestricted or discretionary funds in the operating budget; and
- the need to use operating revenues for the purchase, modification or construction of buildings suitable for academic use.

Among those major universities with which we compare, our endowment is the smallest in relation to operating expenses. The reason can be traced to our continued rapid growth relative to other universities, the unusually high expenses associated with our laboratory-intensive instruction and research, and the relatively few decades we have had to build our endowment.

The Institute will soon embark on a major initiative to significantly increase endowment. During the past year major planning efforts have been undertaken by members of the MIT Corporation. Under the leadership of the Provost, Faculty and Staff have been developing needs and priorities for the forthcoming fund-raising campaign. The objective of this exercise is to accurately define the needs of the various schools and support areas and to determine the magnitude of the increased endowment necessary to meet these needs. It has required extensive analysis and meetings, but the planning should have significant effect in properly explaining the varied needs of MIT to prospective donors.

The needs so far defined include graduate and undergraduate financial aid, faculty chairs, new program initiatives, curriculum development, new facilities and facility renovation. While the exact dollar requirement has not been fully developed, the needs and priorities as articulated and refined show a requirement for a major increase in our present endowment.

These preliminary set of priority needs provide the resource development organization the guidance it requires to take the next steps in the development of specific proposals which can be used to respond to donor interests.

By the time the campaign is officially announced, final priorities and dollar amount will have been decided.

The four or five years required in an intensive drive for endowment funds will involve a significant amount of effort on the part of many Faculty and Staff and the increased commitment of our Corporation members and other volunteers. It is hoped, however, that wide participation in defining needs, priorities and the strategies to raise funds will ensure the success of the effort.

The reports that follow highlight the activities in the five major areas of financial operations. On July 1, 1985, the Office of Purchasing and Stores transferred reporting responsibility from the Senior Vice President to the Vice President for Financial Operations and the Property Office, formerly a division of the Office of Facilities Management Systems, transferred reporting responsibility from the Senior Vice President to the Comptroller. Both of these changes were initiated to increase operating efficiency and to provide better service to the user community through closer connection to other units in the Financial Operations area.

The reports of each department highlight the major activity that has occurred during the year. These brief reports cannot describe, however, the care and effort that individuals in the financial area put into their job, whether it is counseling students or staff, ensuring accounting entries are valid and correct, verifying budget data, ensuring research proposals are in accordance with policy, assisting the MIT community in the procurement of goods and services, or assuring that people are paid correctly. These, and other tasks, are the ones performed so thoroughly and effectively by each individual during the year that make the end results possible. My sincere thanks to all of these individuals.

JAMES J. CULLITON

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## Office of the Comptroller

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### THE COMPTROLLER'S ACCOUNTING OFFICE - CAMBRIDGE

#### General Ledger and Accounts Payable

Beginning in Fiscal Year 1985, the Comptroller's Accounting Office instituted a program to assume responsibility for maintenance of software developed for the Purchase Order Commitments and Accounts Payable computerized systems. This program was expanded in Fiscal Year 1986 to include maintenance of the General Ledger and Chart of Accounts computer applications which will be assumed early in Fiscal Year 1987. This program is consistent with the "Administrative Systems Strategic Plan" developed under the direction of Professor James D. Bruce, Vice President for Information Systems, which supports decentralized management of the administrative software development and maintenance budgets.

#### Payroll

During August 1985, we completed and implemented new MIT Student and Voucher Payrolls. This represented the third and fourth steps, respectively, involving the redesign and conversion of five independently processed computer payroll systems into a single-based system executed on a weekly frequency. Progress on the conversion of the Staff Payroll System was interrupted while the existing Staff Payroll was transferred to the International Business Machines (IBM) "C" computer in Building W91 in the interest of deactivating the IBM "B" computer in the Ford Building on which it was being executed. Following that transfer, resources were redirected to the redesign and conversion of the Staff Payroll.

#### Benefits Accounting

The Pension Accounting System produced actuarial data, early retirement supplement information, and members' annual statements for the first time. Development continued on bulk payments, forecasting, and disbursement aspects. The 1985 Past Service Benefit was implemented in the Retirement Plan for Employees.

#### Travel Accounting

In the fall of 1985, the Institute negotiated Corporate Rates with many local hotels. In the spring of 1986, it was announced by the Ad Hoc Travel Committee that the Institute Authorized Travel Agencies are: Heritage Travel, Raymond & Whitcomb Company, and Topaz Travel.

### THE LINCOLN LABORATORY FISCAL OFFICE

The Lincoln Laboratory Fiscal Office concentrated on developing automated control systems and improving the operational programs; in particular, working out program problems with special emphasis on the payroll systems.

### THE PROPERTY OFFICE

The Property Office is responsible for the accounting and asset management of more than 150,000 items of both Institute-owned as well as sponsor-owned equipment. During the past year, more than 10,600 newly acquired items of movable equipment were identified and tagged. Over 100,000 purchase orders were reviewed to verify equipment purchases, and 7,500 invoices pertaining to equipment were processed. The first biennial inventory of existing items of movable equipment was completed in December 1985 with approximately 150,000 items being identified. Over 220 final inventories were submitted to government sponsors as part of close-out procedures for contracts, grants, agreements, etc. There were 177 financial reports prepared and submitted to various government agencies. Almost \$746,000 (original acquisition cost) of excess Federal Government equipment was acquired as well as \$43,000 of surplus state equipment. Also, five new items of equipment and materials with an approximate value of \$5,500 were acquired from the National Association for the Exchange of Industrial Resources and distributed to departments having requests on the specific needs list maintained by the Property Office. Approximately 689 items of equipment with an acquisition value of \$642,423 were transferred between Institute departments for reutilization. Equipment, not needed or not usable by the Institute community, was sold for \$292,301. Most of the equipment available for reutilization or sale continued to be displayed at the Equipment Exchange. The annual indirect cost study for the equipment pool was completed in conjunction with the Comptroller's Accounting Office and resulted in a conversion from a use basis of cost recovery to a depreciation basis. Under the use basis, a standard useful life of 15 years was required. On the depreciation basis, the inventory has been divided into 13 asset classes with useful lives ranging from

six years to 20 years. Monthly reconciliation of the Comptroller's Accounting Office records with the Property Office records continued with very positive results. The Property Office data base was maintained using the INSITE 3 data base management system. Over 10,000 additions and over 121,000 changes to the data base were processed. The operation of the Storage Facility at 224 Albany Street (NW30) continued, providing short-term storage to 50 departments, for the temporary six-month storage needs of the Institute community. The Society for Property Administrators (SPA), which is administered by the Property Office, conducted a three-day Property Management Conference in New Orleans, Louisiana in November 1985. More than 135 attendees from the United States and Canada were present at the conference. A quarterly newsletter was also published and distributed to the nearly 300 society members.

#### THE AUDIT DIVISION

For the Audit Division, Fiscal Year 1986 can best be characterized by the two themes of growth and change. In terms of staff size, early Fiscal Year 1986 saw one newly created position filled and two established positions become available and then quickly filled. A degree of standardization of workpaper techniques was introduced, and the role of audit reviewer at the staff level was redefined to involve a reviewer as an active member of each audit team from the inception of the audit. The Audit Division continues to provide its traditional service of verification that management policies and procedures are being implemented as intended, that adequate internal controls are being maintained, and that assets are properly safeguarded. This is being done, however, in an ever more computer-driven and computer-dependent environment. In order to meet the needs of our changing environment, the Audit Division is acquiring a broader Electronic Data Processing (EDP) knowledge base. The staff is accessing various data files on VAX's, Personal Computers (PC's), and IBM mainframes; evaluating the use of data processing in determining the scope and objectives of an audit; developing a detailed audit plan for the majority of audits; evaluating new audit software for use on PC's; and is involved in the general control aspects of information systems (e.g. password change enforcement, procedures upon termination, program modification control, and program library and tape library controls). Involvement in the design phase of new systems development should result in early detection and correction of controls which are inadequate or incomplete. This should be cost efficient in the long run compared to the expense of bringing inadequate controls to an acceptable level at a later stage when the same system is operational. Fiscal Year 1986 also saw the issuance by the Institute of "A Proposed Administrative Systems Strategic Plan." The immediate impact on the Audit Division of the "Strategic Plan" has been the creation of another new position on the audit staff so as to enable EDP specialists within the Audit Division to be available for more specific and more technical audit coverage. The long-term impact of the "Strategic Plan" remains to be seen, but we expect the Audit Division to continue to change along with our environment at the Institute.

#### Personnel Changes

The following staff changes occurred within the Comptroller's Office during the past year:

<u>Appointments</u>	<u>Promotional Appointments</u>	<u>Promotions</u>	<u>Retirements</u>
Joanne C. Barrett Assistant Accounting Officer	William P. Cataldo Staff Accountant	Demetri A. Karageorge Senior Staff Accountant	Roberta F. Burns 32 years' service
Thomas Curran Property Auditor	Denise E. Ferry Staff Accountant	Edith A. Klotz Senior Staff Accountant	Doris M. Marzioni 27 years' service
Victoria T. Harmon Auditor	Michael J. Glynn Applications Programmer	Kathleen M. Lalor Accounting Officer	Joseph B. Paiva, Jr. 13 years' service
Lloyd M. Harte, Jr. Auditor	Ann M. Langton Staff Accountant	Stanley Miller Assistant to the Comptroller	
Elizabeth Mattson Analysis Applications Programmer	Anne Mahoney Staff Accountant	Joseph B. Paiva, Jr. Senior Staff Accountant	
Sheriefa Siers Applications Programmer	Frank J. Silva, Jr. Staff Accountant		
Pamela S. Williams Auditor	Maria Tantoulos Staff Accountant		

PHILIP J. KEOHAN

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## Office of the Director of Finance

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The prices the Institute charges for its services are set well in advance of the beginning of its fiscal year. As a result the financial outcome for any year is dependent, to a large extent, on the actual rate of inflation, gifts received, and sponsor support matching or exceeding the assumptions made when rates were set. On all of these counts the Institute did well in fiscal 1986 ending the year with a surplus of \$1,507,000. This is the third surplus in five years and the seventh in the last decade.

The inflation rate in the general economy grew a modest two percent during the year for US urban workers. In contrast MIT's modified total direct cost base for research, which is a good measure of real growth, grew by 5.7 percent for its campus activities and by 13.1 percent in its off campus research activities (primarily Lincoln Laboratory). In addition, gift receipts continued at the strong level experienced in the last few years.

Total operating expenses reached \$790,803,000 — up 10.3 percent from the previous year. Total operating revenues and funds used were \$789,184,000 — an increase of 10.5 percent over 1984-85. The difference between these two numbers (referred to as the "operating gap" or the "additional need for unrestricted revenues and funds") provides a good measure of the Institute's progress in dealing with financial constraints over the last decade. In fiscal year 1977 the "operating gap" was \$3,864,000 while in fiscal year 1986 it was \$1,619,000. As a percentage of total operations the operating gap has declined from 1.4 percent in fiscal year 1977 to 0.2 percent in fiscal year 1986. This statistic, combined with a knowledge of the new initiatives and ventures undertaken by MIT over the last decade, is a considerable tribute to the strength of the MIT faculty and their ability to draw support for their efforts from a broad spectrum of sources, both public and private.

To meet the operating gap there are unrestricted revenues from gifts, grants, and bequests. In fiscal year 1986 these sources totalled \$3,126,000. To fund the operating gap required \$1,619,000 of these sources, leaving a surplus of \$1,507,000. In addition the Institute was able to add \$4,327,000 to its reserve for the acquisition and renovation of its physical plant.

On October 10, 1985, \$22,430,000 of Massachusetts Health and Educational Facilities Authority-Massachusetts Institute of Technology Series F bonds, were sold at a net interest cost to the Institute of 7.6 percent. These bonds were sold primarily in support of the acquisition and installation of a digital switching system capable of transporting voice, data, video, and facsimile signals. In addition, a portion of the bonds were used to purchase mainframe computing equipment used primarily for educational and research purposes. This collateralized issue was rated AAA by Standard and Poors and aa+ by Moody's Rating Service.

In fiscal year 1986 the Budget Office continued to enhance its "local area computer network" that links together individual computer work stations to the office's database. This state of the art system has improved our ability to perform special financial analyses and to help the MIT community in their budgeting work. The mainframe budget system being prepared by the Administrative Systems Group continues in the programming and testing phase.

### PERSONNEL

During the year Catherine Ormond resigned to accept a position as Administrative Officer in the Physics Department. Mary E. Gibson was promoted to Budget Officer II, and John R. Mason to Budget Officer I. Frances L. Barboza was appointed to the position of Budget Officer II and Gregory R. Arsenault as a Programmer-Analyst.

JOHN A. CURRIE

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## Office of Purchasing and Stores

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Major projects accomplished or initiated this year include:

- 1) An automated, on-line Cylinder Control and Billing System became operational in September. The system is used to track the receipt, location, and return to vendors of the 7,500 compressed gas and liquid cylinders on campus. In addition, the System enables charging user accounts directly for the monthly demurrage (rental) costs they incur in connection with the gases and liquids they utilize, thereby eliminating this expense from Institute overhead.
- 2) Development of a fully automated, integrated, on-line Purchasing, Accounts Payable, and Receiving System commenced in January as a joint project of the Department of Purchasing and Stores and the Comptroller's Accounting Office. The System will allow all purchasing offices, research laboratory purchasing agencies and fiscal offices, Accounts Payable, and other administrative offices to create, print, store, display, and process entire purchase order and invoice and receiving information on-line. The System is expected to be ready for implementation in April of the coming year.

The System being developed is part of this Department's long-range plans for providing electronic requisitioning capabilities throughout the Institute, and for providing electronic access to purchasing information to the academic and research sectors of the Institute. In line with these plans, system development is being closely coordinated with other administrative departments to ensure as fully an integrated system as possible, and to ensure conformance with the goals outlined in the Strategic Plan for Administrative Computing developed by the Information Systems Department.

### General Purchasing Office

Purchasing activity for the year continued at the previous year's level. Major emphasis continued to be placed on negotiating discount agreements with suppliers.

### Office of Laboratory Supplies

Combined sales of office and laboratory items and furniture and furnishings decreased 10 percent from the previous year. While sales of office and laboratory items continued at the same level, sales of furniture and furnishings decreased 33 percent. This significant decrease resulted from the reduction of major building renovations and the absence of new building completions this year.

The established Office of Laboratory Supplies' systems for purchasing, receiving, storage, inventory control, delivery, coordination with the Property Office, and internal billing continued to be utilized to support the Microcomputer Center's personal computer resale programs.

### Minority and Women-Owned Business Purchasing Programs

Business placed Institute-wide under these affirmative action procurement programs resulted in the award of over \$7.0 million to minority and women-owned business concerns. For the first time, the Institute exceeded the \$3.0 million level in awards to both minority and women-owned business concerns. Over \$3.6 million was awarded to 262 minority businesses and over \$3.4 million was awarded to 624 women-owned businesses. Accomplishments this year represent a 20 percent increase over the previous year.

BARRY ROWE



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## Office of Registration and Student Financial Services

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### BURSAR'S OFFICE

#### Overview

The past year was a year of several major accomplishments in the Bursar's Office. We have affirmed the importance of service to MIT students in our mission through: improving collaboration with the Student Financial Aid Office, the Dean for Student Affairs Office, the Office of the Dean of the Graduate School, and the Registrar's Office, to help students in financial difficulty; renaming of the Student Accounts section of the office; hiring of an Associate Bursar to manage that section, among whose responsibilities will be to act in the capacity of ombudsman for students; and offering of an IAP course on "Personal Financial Planning" in conjunction with the Student Financial Aid Office.

In the area of staffing changes, we have defined or redefined responsibilities of three senior administrative staff and hired new people into two of those positions, and have made progress on the equal employment opportunity front.

Because our current loan electronic data processing system is unable to provide us with the management information and the support for effective functioning of our collection process that it must, and because it is unnecessarily costly and time consuming for us to develop our own in-house system to meet our growing requirements when such systems exist at a reasonable cost in the marketplace, we have decided on an appropriate outside vendor for those services. We have written our own contract, resolved issues related to privacy and security, and are close to having the contract signed and the conversion process started.

We have tightened the security of our office, to protect our valuable papers, equipment, and personnel.

And, finally, our measures of financial performance remain excellent. Default rates on NDSL and GSL/FISL loans reached an all-time low for MIT this year.

Reports from each of the sections follow.

#### Student Services

The Student Accounts section of the Bursar's Office was renamed Student Services, which represents an affirmation of the importance of service to MIT students.

Student tuition, fees, and other charges totaling \$123,472,835 were billed, an increase of 8.7% from last year. Servicing the 10,000 student accounts required 214,113 transactions to the student accounts receivable system, and an average of three personal contacts were made with each student by an Assistant to the Bursar/Student Services.

Income from late payment fees was \$61,906 and income from finance charges was \$180,784.

#### Student Loans

Student loans receivable amounted to \$38.3 million at the close of the fiscal year. These notes are funded by \$11,258,374 of MIT loan funds established by friends and alumni of the Institute, \$19,194,665 of federal funds in support of the National Direct Student Loan (NDSL) program, \$168,174 borrowed from the federal government to support a portion of our contribution to the NDSL program, \$4,558,765 borrowed from the Student Loan Marketing Association (SLMA), and \$3.1 million borrowed from local banks.

MIT's Parent Loan Program, established in 1977 to assist parents of students receiving little or no financial aid, continued to grow slowly. There are now 632 active accounts with an outstanding balance of \$3,941,235. A total of \$2,820,000 was disbursed during the year and principal collected totaled \$2,557,990. This program is fully funded by a loan from SLMA.

#### Student Loan Collection

The delinquency rate as a percent of active loans remained constant this year at 22.9%, despite the fact that loan receivables increased 5.1% to \$38,276,807 and loans in active status rose 8.2% to \$22,633,043.

MIT's default rate on National Direct Student Loans (NDSL) decreased from 1.6% in 1984 to 1.2% in 1985; our default rate on Federal Insured Student Loans (GSL/FISL) decreased from 2.4% in 1984 to 1.7% in 1985. The 1985 national default rates were 8.2% for NDSL and 9.1% for GSL/FISL.

The Department of Education has published a new formula for calculation of the NDSL default rate for 1986 which will negatively affect all NDSL lenders. Our projections indicate that our default rate under the new formula will at least double.

Our experience with international collections has helped us to understand the repayment problems many of our alumni borrowers encounter after returning to their respective countries. We visited the major consulates in Boston and New York and, in most instances, received their full cooperation. Their continued support should help us to offer information to our students and alumni borrowers on methods of transferring funds, impediments or restrictions which may be imposed by their countries, and loans or scholarships which may be available from their governments.

#### Information Systems

Plans are under way to convert our current in-house student loan billing and data processing operation to a state-of-the-art system offered by an outside vendor. This conversion is expected to yield significant benefits to our alumni borrowers by providing them with a wider range of billing services and payment options not currently offered through our in-house operation. Our internal loan servicing staff will have direct on-line access to the system and will be supported with a complete range of accounting and management reports. Programming services will also be provided to tailor the system to the needs and expectations of MIT. We anticipate that the range of MIT's alumni counseling and collection services can be expanded utilizing the increased capabilities of the new system. Conversion is planned for the fall of 1986.

Word processing support for our student loan collection function was transferred from an old DECMATE system to a more modern and efficient IBM PC system, complete with file query and expanded word processing capabilities. This allowed us to devote more attention to the individual needs of our alumni borrowers.

The main data files of our existing student loan system are now being copied on a regular basis and stored off-site from MIT's main administrative computing facilities. This action is part of our overall plan to promote increased awareness of security issues and to ensure the continued operation of the system in the event of loss or damage to data media at the main storage site.

#### Staff Notes

Carlene Chisom-Freeman joined our staff as Assistant to the Bursar/Loan Collection in September. She came to MIT from Home Savings Bank, where she was Assistant Treasurer of the Consumer Loan Department.

Janet E. Fischer joined our staff as Assistant to the Bursar/Student Services in March. She came to MIT from Quissett Corporation (a firm specializing in personal financial planning), where she was a Junior Analyst.

Kate Wilson joined our staff as Associate Bursar/Student Services in May. She came to MIT from San Diego State University, where she was Director of Financial Aid.

Eleanor C. Wolcott was promoted to the position of Assistant to the Bursar/International, Collection Agency, and Attorney Accounts.

Joanne C. Barrett resigned her position as Assistant Bursar/Student Accounts in November to join the staff of the MIT Payroll Office.

Jeanne M. Hillery resigned her position as Assistant to the Bursar/Control & Accounting in November to join the staff of the MIT Laboratory for Nuclear Science.

John F. O'Brien, Jr. resigned his position as Assistant Bursar/Systems Integration & Control in March to join the staff of the MIT Department of Mechanical Engineering.

#### REGISTRAR'S OFFICE

##### Enrollment

In 1985-86 student enrollment was 9,787, compared with 9,626 in 1984-85. This total was comprised of 4,541 undergraduates (compared with 4,536 the previous year), and 5,246 graduate students (compared with 5,090 the previous year). Graduate students who entered MIT last year held degrees from 412 colleges and universities, American and foreign. The International student population was 2,249, representing 13% of the undergraduate and 31% of the graduate population. These students were citizens of 96 countries.

In 1985-86, there were 2,218 women students (1,176 undergraduate and 1,042 graduate) at the Institute, compared with 2,211 (1,157 undergraduate and 1,054 graduate) in 1984-85. In September 1985, 290 first-year women entered MIT, representing 27% of the entering class.

In 1985-86, there were 1,241 minority\* students (1,047 undergraduate and 194 graduate) at the Institute, compared with 1,189 (1,021 undergraduate and 168 graduate) in 1984-85. The first year class entering in September 1985 included 285 minority students representing 27% of the class.

#### Degrees Awarded

Degrees awarded by the Institute in 1985-86 included 1,231 bachelor's degrees, 1,059 master's degrees, 54 engineer's degrees, 455 doctoral degrees -- a total of 2,799.

#### Tabular Presentation

Most of the above 1985-86 figures are taken from the several tables which follow. These tables, together with others dealing primarily with historical comparison and demographic data, comprise the annual Registrar's Report, separately published and available upon request.

#### STUDENT FINANCIAL AID OFFICE

Although the year was marked by the usual increases in important descriptors of the aid program -- increases in the need for aid, in the volume of awards in most categories, and in the level of concern that federal support of student aid is eroding -- we saw emerging for the first time new kinds of change.

Confirming the hint of a trend established last year, but deemed inconsequential enough not to be entered in the record then, we saw the number of students needing financial aid decrease. And we saw the long-steady pattern of income distribution (among freshman applicants for aid) exhibit a side-shift to the affluent end of the spectrum. The magnitude of the changes remains modest -- the loss of five students needing help (out of 2460), and an increase of five percentage points out of 40 in the fraction of applicants who are children of families defined as "high income" in national statistics. But the trend is now unmistakable, and confirms expectations that the cuts in the national income tax rates would have the effect of generating proportionally more disposable income for our families. This has made them just that much less needy than otherwise, and, perhaps, helped some families to opt for a more expensive college than would otherwise have been the case.

But as implied in the first paragraph of this section, these effects were not large enough to offset the increase in costs passed to our students; and so the aggregate need for assistance (to a smaller population than last year) rose 12%, to a new high of \$26,292,000.

#### Scholarship and Grant Programs

Scholarships and grants awarded increased by six percent over last year. Slight increases in awards from the two federal programs generally available to needy students at all colleges, offset by another decline in ROTC scholarships received by students with need, netted in a slight decline in the federal subtotal. (It is significant to note that any increase in federally-funded programs is counter to the apparent downward trend so frequently referenced in the popular press.)

We note, too, an unusually large increase in grants provided by investment income from the endowment provided for this purpose; and one of the largest increases ever in the level of scholarships provided directly to students from non-federal agencies outside the Institute.

In all, the year was certainly "positive" in all areas respecting scholarships and grants. The following table presents details for three consecutive years.

\*Minority students include 295 Blacks (non-Hispanic), 22 Native Americans, 234 Hispanics, and 690 Asian Americans.

**Scholarships and Grants\***  
(awarded to undergraduates with need)

<u>Source</u>	<u>1983-84</u>	<u>1984-85</u>	<u>1985-86</u>
Pell Grants	\$ 761,000	\$ 755,000	\$ 825,000
SEO Grants	1,111,000	1,294,000	1,329,000
ROTC Scholarships	998,000	928,000	840,000
Scholarship Endowment	3,831,000	3,953,000	4,440,000
Current Gifts	601,000	739,000	800,000
Direct Grants	1,460,000	1,644,000	1,819,000
Special Program	115,000	118,000	94,000
<u>Unrestricted Funds</u>	<u>5,871,000</u>	<u>5,432,000</u>	<u>5,586,000</u>
	\$14,748,000	\$14,863,000	\$15,733,000

Loan Programs

Here, too, the national outcry over devastating cuts in federal programs simply was proven mis-directed. Another record use of the National Direct Student Loan Program, and continued steady use of the Guaranteed Student Loan Program combined to allow considerable moderation in the need to tap MIT's own (already over-loaned) Technology Loan Fund. Although the aid plan for the year called for increasing the self-help level (student loans and term-time work in combination) by \$300 to (\$4900), these three sources were adequate to meet the demand for student loans.

The following table details loan use by undergraduate and graduate students.

Loans

(received by needy and non-needy students)

<u>Source</u>	<u>1983-84</u>	<u>1984-85</u>	<u>1985-86</u>
<u>A. Awarded to Undergraduates</u>			
Technology Loan Fund	\$ 484,000	\$ 738,000	\$ 823,000
National Direct Loans	1,934,000	2,347,000	2,452,000
<u>Guaranteed Student Loans</u>	<u>5,982,000</u>	<u>5,719,000</u>	<u>5,629,000</u>
Sub-Total	\$8,400,000	\$8,804,000	\$8,904,000
<u>B. Awarded to Graduate Students</u>			
Technology Loan Fund	\$1,632,000	\$1,420,000	\$1,396,000
Guaranteed Student Loans by Commercial Lenders	3,011,000	3,390,000	3,395,000
<u>Guaranteed Student Loans by MIT</u>	<u>228,000</u>	<u>202,000</u>	<u>120,000</u>
Sub-Total	\$4,871,000	\$5,012,000	\$4,911,000

\*All of the numbers reported in this section reflect awards from the academic year perspective, and so will not agree exactly with fiscal-year-based accounting records reported by the Comptroller or the Treasurer.

### Student Employment

1985-86 showed a very strong job market, and the average starting rate for off-campus jobs was well above the Federal minimum wage. The on-campus minimum wage was increased to \$5.50. The number of students working on-campus remained constant.

The College Work-Study Program allocation increased slightly over the 1984-85 funding level and was used entirely to subsidize the on-campus student employment program. Approximately two-thirds of the total 1985-86 allocation was used to subsidize undergraduate work, and one-third to subsidize graduate student teaching assistantships.

### Moving the Limits of the SFAO's Mission

The SFAO's mission is clearly to help students attend MIT whose parents cannot provide the full costs. But in the course of fixing the appropriate level of aid for each applicant, there is frequently a counseling dialogue with the parents shouldering their proportional burden of the costs. From this experience, MIT launched its Parent Loan Plan in 1977, out of a desire to take the sting out of the parents' "contribution". The past year has seen the rapid development, within other universities and within commercial and quasi-public agencies, of a number of programs designed -- like our PLP -- to help parents meet the costs of education.

These programs, for the most part, are interchangeable with each other and with the PLP, and to the parents of our students represent a confusing array of options for them. While it is a simple matter for us to advise parents to seek advice from a third party, we are finding that in these matters the SFAO and the Bursar's Office in combination are probably the most competent and well-informed counseling source in existence for most parents. So we are together addressing the ways in which we can be of greatest service to these valued "clients" of ours.

### Staff Notes

During the year, Lisa A. Oteri was promoted to Assistant Director, and continues to complement her role as counselor with significant contributions to the production and management of data important to the Office.

As the year ended, we were pleased to welcome Steven Nalesnik '86 to the staff, as Assistant to the Director for Systems Management and Research.

JACK H. FRAILEY

## ACADEMIC STAFF COUNT

	Professors*	Administration also Professors	Institute Professors* Emerti-Part Time*	Adjunct Professors*	Associate Professors*	Assistant Professors*	Sr. Lecturers and Professors Emerti	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Sr. Research Associates	Postdoctoral Associates	Research Assistants	Teaching Assistants	Instructor Grad	Total	Visiting Professors	Others†
Institute Professors	14	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	1	-
SCHOOL of ARCHITECTURE AND PLANNING																				2
Architecture	13	2	-	4	12	7	1	-	13	-	2	4	-	-	63	54	2	177	6	15
Urban Studies and Planning	15	1	-	2	3	4	1	2	5	-	-	-	-	-	37	6	-	76	4	29
Total	28	3	-	6	15	11	2	2	18	-	2	4	-	-	100	60	2	253	10	46
SCHOOL OF ENGINEERING	1	1	-	-	3	-	1	-	1	-	-	-	-	-	-	-	-	7	1	-
Aeronautics and Astronautics	23	2	-	2	7	10	4	6	11	-	-	3	-	4	135	6	-	213	-	13
Chemical Engineering	17	2	-	1	5	5	-	1	2	-	2	1	1	7	128	26	1	199	-	20
Civil Engineering	20	4	-	-	12	7	1	1	5	-	-	-	-	5	123	30	2	210	1	9
Electrical Engineering and Computer Science	55	14	-	6	26	17	4	-	11	3	-	4	1	2	283	127	1	554	3	14
Materials Science and Engineering	19	4	-	1	8	4	2	-	-	-	-	2	2	15	191	18	-	266	1	37
Mechanical Engineering	26	4	-	1	20	6	5	6	23	1	-	5	1	4	271	25	1	399	6	24
Nuclear Engineering	15	2	-	-	4	3	-	-	-	-	-	-	-	-	61	19	-	104	4	9
Ocean Engineering	13	1	-	-	6	4	-	1	5	-	-	-	-	7	43	11	-	91	2	12
Total	189	34	-	11	91	56	17	15	58	4	2	15	5	44	1,235	262	5	2,043	18	138
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE	1	-	-	-	-	-	-	1	8	-	-	3	-	-	-	-	-	13	-	1
Economics	18	2	-	-	4	4	-	-	-	-	1	-	-	-	21	30	-	80	2	10
Humanities	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthropology/Archaeology	2	-	-	-	4	2	-	-	1	-	-	-	-	-	-	-	-	19	-	1
Foreign Languages and Literature	2	1	-	-	6	5	-	1	14	-	-	-	-	-	-	-	-	29	-	2
History	6	1	-	-	3	3	-	-	-	-	-	-	-	-	-	-	-	13	-	-
Literature	5	2	-	-	7	3	-	-	10	-	-	-	-	-	-	-	-	27	-	-
Music	6	1	-	-	2	-	-	2	8	-	-	1	-	-	-	-	-	20	-	16
Writing Program	1	1	-	1	4	4	-	1	5	-	-	6	-	-	-	-	-	23	-	4
Linguistics and Philosophy	11	2	-	-	4	4	-	-	1	-	-	-	-	-	23	12	-	57	2	6
Political Science	13	2	-	1	6	3	1	1	4	-	-	-	-	-	48	9	-	88	1	3
Psychology	11	2	-	1	4	1	-	-	-	-	-	3	-	7	12	4	-	45	-	18
Science, Technology and Society	5	1	-	-	3	-	1	-	-	-	-	-	-	-	-	3	-	13	1	27
Total	81	15	-	3	47	29	2	6	51	-	1	13	-	7	104	58	-	417	6	88
SLOAN SCHOOL OF MANAGEMENT																				
Management	37	2	-	2	23	15	1	7	4	-	-	1	-	-	31	60	-	183	7	19
SCHOOL OF SCIENCE																				
Applied Biological Sciences	9	3	-	1	3	4	3	4	6	-	-	-	-	26	65	7	-	131	1	94
Biology	31	3	-	-	2	10	1	-	1	1	4	-	1	55	17	3	-	129	-	75
Chemistry	23	2	-	-	3	4	3	-	1	-	-	1	-	71	135	48	-	291	2	54
Earth, Atmospheric, and Planetary Sciences	20	2	-	-	8	9	1	1	-	2	1	-	-	17	89	14	-	164	6	24
Mathematics	34	1	-	-	12	5	-	1	1	-	21	-	-	1	20	53	-	149	3	16
Physics	65	6	-	-	8	8	1	-	-	14	-	5	-	7	199	31	-	344	1	17
Total	182	17	-	1	36	40	9	6	9	17	26	6	1	177	525	156	-	1,208	13	280

Administration	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Air Force Aerospace Studies	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	1	-
Artificial Intelligence Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	4
Athletic	-	1	-	-	9	5	-	-	-	12	-	-	-	-	-	-	-	17
Biotechnical Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27	-	1
Center for Advanced Engineering Study	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Center for Advanced Visual Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
Center for Cancer Research	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53
Center for Cognitive Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24
Center For International Studies	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
Center for Technology Policy, and Industrial Development	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Center for Materials Research in Archaeology and Ethnology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Center for Materials Science and Engineering	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
Center for Space Research	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	5
Clinical Research Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Division of Comparative Medicine	-	1	-	-	-	-	-	-	-	-	5	-	-	-	-	6	-	6
Energy Laboratory	-	-	-	-	-	-	-	-	2	-	1	2	-	-	-	5	-	17
Francis Bitter National Magnet Laboratory	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	42
Harvard-MIT Health Sciences and Technology	1	-	-	-	2	2	-	-	2	1	-	-	5	13	7	33	1	22
Haystack Observatory	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-
Laboratory of Architecture and Planning	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	13
Laboratory for Computer Science	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	20
Laboratory for Electromagnetic and Electronic Systems	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
Laboratory for Information and Decision Systems	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	10
Laboratory for Manufacturing and Production	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
Laboratory for Nuclear Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
Materials Processing Center	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	4	-	13
Media Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
Medical	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	156
Military Science	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	8	1	-
Naval Science	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	6	2	-
Nuclear Reactor Laboratory	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
Office of the Provost	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Operations Research Center	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Plasma Fusion Center	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	3	-	10
Project Athena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30
Research Laboratory of Electronics	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	4	-	61
Sea Grant Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Spectroscopy Laboratory	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	5
Statistics Center	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	5
Student Activities	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	6	-	-
Technology and Development Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Whitaker College of Health Sciences, Technology and Management	2	-	-	-	3	-	-	-	-	-	-	7	-	-	-	12	-	27

Total	4	5	-	-	12	2	-	-	2	15	12	28	1	29	13	7	-	138	5	654
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GRAND TOTAL	535 <sup>2</sup>	76 <sup>2</sup>	2 <sup>2</sup>	23 <sup>2</sup>	226 <sup>2</sup>	158 <sup>2</sup>	31 <sup>2</sup>	36 <sup>2</sup>	142 <sup>2</sup>	36	43 <sup>2</sup>	67 <sup>2</sup>	7	257	2,009	602 <sup>2</sup>	7 <sup>2</sup>	4,257	60 <sup>3,4</sup>	1,225 <sup>3</sup>
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Faculty Ex-Officiis

34

4,291

\*Total Faculty 1,121

<sup>1</sup>Includes Administrative Officers, affiliated Artists, Coaches and Trainers, Guests, Honorary Lecturers, Institute Organist, Visiting Lecturers and Senior Lecturers, Medical Doctors, Nurses, Postdoctoral and Research Fellows, Postdoctoral Trainees, Research Affiliates, Senior Research Engineer, Visiting Economists, Visiting Engineers and Senior Engineers, Visiting Research Associates, Visiting Scholars, Visiting Scientists, Visiting Writers.

<sup>2</sup>Total Teaching Staff 1,948

<sup>3</sup>Not included in preceding total

<sup>4</sup>Visiting Professors include 27 Professors, 23 Associate Professors, 10 Assistant Professors

CLASSIFICATION OF STUDENTS BY SCHOOLS, COURSES AND YEARS, 1985-86

COURSE NAME	ALL STUDENTS						SPECIAL STUDENTS*					
	2	3	4	G	Non Res. 1	Total	2	3	4	G	Total	
SCHOOL OF ARCHITECTURE AND PLANNING												
Architecture, IV	16	26	25	246	11	257	-	-	-	7	7	IV
Architecture, IV-B	2	-	1	-	-	3	-	-	-	-	-	IV-B
Urban Studies and Planning, XI	-	2	2	184	30	218	-	-	-	23	23	XI
Total	18	28	28	430	41	543	-	-	-	30	30	Total
SCHOOL OF ENGINEERING												
Aeronautics and Astronautics, XVI	109	76	89	236	1	511	-	-	-	15	15	XVI
Aeronautics and Astronautics, XVI-B (Cooperative)	-	-	1	-	-	1	-	-	-	-	-	XVI-B
Aeronautics and Astronautics, XVI-C (Internship)	-	15	11	-	-	26	-	-	-	-	-	XVI-C
Chemical Engineering, X	49	61	55	228	-	393	-	-	-	6	6	X
Chemical Engineering, X-C (Cooperative)	-	1	-	-	-	1	-	-	-	-	-	X-C
Civil Engineering, I	28	22	28	247	1	248	-	-	-	9	9	I
Civil Engineering, I-W (Woods Hole)	-	-	-	6	-	6	-	-	-	-	-	I-W
Electrical Engineering and Computer Science, VI												
Program 1-Electrical Science and Engineering	213	198	205	638	1	1,564	-	-	-	74	78	VI
Program 3-Computer Science and Engineering	103	80	126				1	3	-			
Electrical Engineering and Computer Science, VI-A (Cooperative)	-	58	70	93	-	289	-	-	-	-	-	VI-A
Program 1-Electrical Science and Engineering	-	32	36				-	-	-			
Program 3-Computer Science and Engineering												
Electrical Engineering and Computer Science, VI-W (Woods Hole)	-	-	-	3	-	3	-	-	-	-	-	VI-W
Materials Science and Engineering, III	30	16	18	290	1	355	-	-	-	12	12	III
Materials Science and Engineering, III-A	-	-	3	-	-	3	-	-	-	-	-	III-A
Materials Science and Engineering, III-B (Cooperative)	15	31	24	-	-	70	-	-	-	-	-	III-B
Mechanical Engineering, II	144	107	123	465	2	841	-	-	-	26	26	II
Mechanical Engineering, II-A	14	12	10	-	-	36	-	-	-	-	-	II-A
Mechanical Engineering, II-B (Internship)	-	24	23	-	-	47	-	-	-	-	-	II-B
Mechanical Engineering, II-W (Woods Hole)	-	-	-	4	-	4	-	-	-	-	-	II-W
Nuclear Engineering, XXII	11	4	7	148	2	172	-	-	-	-	-	XXII
Nuclear Engineering, XXII-A (Internship)	-	1	2	-	-	3	-	-	-	-	-	XXII-A
Ocean Engineering, XIII	3	7	7	87	-	105	-	-	-	7	7	XIII
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	12	-	12	-	-	-	-	-	XIII-W
Naval Construction and Engineering, XIII-A	-	-	-	43	-	43	-	-	-	1	1	XIII-A
Ocean Systems Management, XIII-B	-	-	-	8	-	8	-	-	-	-	-	XIII-B
Center for Advanced Engineering Study, EN	-	-	-	53	-	53	-	-	-	53	53	EN
Total	719	745	839	2,561	8	4,782	1	3	-	202	206	Total



<b>SCHOOL OF HUMANITIES AND SOCIAL SCIENCE</b>												
Economics, XIV	11	20	16	124	14	183	-	-	-	7	7	XIV
Humanities, XXI	5	6	11	-	-	22	-	-	4	-	4	XXI
Humanities and Engineering, XXI-E	1	3	10	-	-	14	-	-	-	-	-	XXI-E
Humanities and Science, XXI-S	2	5	3	-	-	10	-	-	-	-	-	XXI-S
Linguistics and Philosophy, XXIV	2	-	1	57	9	69	-	-	-	1	1	XXIV
Political Science, XVII	3	5	10	140	41	199	-	-	-	5	5	XVII
Political Science, XVII-A (Public Policy)	-	-	1	-	-	1	-	-	-	-	-	XVII-A
Psychology, IX	10	12	15	37	-	74	-	-	1	-	1	IX
<b>Total</b>	<b>34</b>	<b>51</b>	<b>67</b>	<b>358</b>	<b>70</b>	<b>549</b>	<b>-</b>	<b>-</b>	<b>5</b>	<b>13</b>	<b>18</b>	<b>Total</b>
<b>SLOAN SCHOOL OF MANAGEMENT</b>												
Management, XV	27	37	30	426	9	529	-	-	-	10	10	XV
Management Fellows, XV-A	-	-	-	58	-	58	-	-	-	4	4	XV-A
Management-Operations Research, XV-B	-	-	-	16	-	16	-	-	-	-	-	XV-B
Management-PH.D., XVP	-	-	-	66	-	66	-	-	-	-	-	XV-P
<b>Total</b>	<b>27</b>	<b>37</b>	<b>30</b>	<b>566</b>	<b>9</b>	<b>669</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>14</b>	<b>14</b>	<b>Total</b>
<b>SCHOOL OF SCIENCE</b>												
Applied Biological Sciences, XX	-	-	-	117	1	118	-	-	-	3	3	XX
Biology, VII	81	62	75	146	-	364	1	-	1	5	7	VII
Biology, VII-A	4	-	11	-	-	15	-	-	-	-	-	VII-A
Biology, VII-B	15	10	14	-	-	39	-	-	-	-	-	VII-B
Biology, VII-W (Woods Hole)	-	-	-	17	-	17	-	-	-	-	-	VII-W
Chemistry, V	22	36	43	224	-	325	-	-	1	-	1	V
Earth, Atmospheric, and Planetary Sciences, XII	14	10	10	117	3	154	-	-	-	1	1	XII
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	69	-	69	-	-	-	-	-	XII-W
Mathematics, XVIII	35	50	51	116	11	263	-	-	3	3	6	XVIII
Mathematics with Computer Science, XVIII-A	18	8	2	-	-	28	-	-	-	-	-	XVIII-A
Physics, VIII	74	64	77	299	3	517	1	-	-	10	11	VIII
Physics, VIII-A	22	2	-	-	-	24	-	-	-	-	-	VIII-A
<b>Total</b>	<b>285</b>	<b>242</b>	<b>283</b>	<b>1,105</b>	<b>18</b>	<b>1,863</b>	<b>2</b>	<b>-</b>	<b>6</b>	<b>22</b>	<b>30</b>	<b>Total</b>
Health Policy and Management, HPM	-	-	-	9	-	9	-	-	-	-	-	HPM
Health Sciences and Technology, HST	-	-	-	77	-	77	-	-	-	45	45	HST
<b>Undesignated</b>	<b>43</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>43</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>Undesignated</b>
<b>First Year</b>	<b>1,065</b>					<b>1,065</b>	<b>-</b>				<b>-</b>	<b>First Year</b>
<b>Grand Total</b>	<b>1,065</b>	<b>1,126</b>	<b>1,103</b>	<b>1,247</b>	<b>5,106</b>	<b>140</b>	<b>9,787</b>	<b>-</b>	<b>3</b>	<b>3</b>	<b>11</b>	<b>Grand Total</b>
<b>(Not included in the above figures)</b>												
Non-Institute students from Harvard	35	20	25	241	-	321						
Non-Institute students from Tufts	29	18	9	-	-	56						
Non-Institute from Wellesley	44	62	68	-	-	174						

<sup>1</sup> Non-Resident graduate students

Not included in the above totals:

7 students in third year, 5 students in the fourth year on Foreign Study.

\* 2 students in the second year, 1 student in the third year on Domestic Study.

Included in preceding.

WOMEN STUDENTS BY SCHOOLS, COURSES AND YEARS, 1985-86<sup>1</sup>

COURSE	UNDERGRADUATE			GRADUATE NON			TOTAL
	2	3	4	REGULAR	RESIDENT	SPECIAL	
SCHOOL OF ARCHITECTURE AND PLANNING							
Architecture, IV	7	8	12	75	4	5	111
Architecture, IV-B	-	-	-	-	-	-	-
Urban Studies and Planning, XI	-	1	1	63	17	9	91
Total	7	9	13	138	21	14	202
SCHOOL OF ENGINEERING							
Aeronautics and Astronautics, XVI	20	10	22	20	-	3	75
Aeronautics and Astronautics, XVI-C (Internship)	-	2	1	-	-	-	3
Chemical Engineering, X	15	21	13	34	-	2	85
Chemical Engineering, X-C (Cooperative)	-	1	-	-	-	-	1
Civil Engineering, I	4	7	8	28	-	3	50
Civil Engineering, I-W	-	-	-	2	-	-	2
Electrical Engineering and Computer Science, VI							
Program 1-Electrical Science and Engineering	44	29	22	95	-	10	249
Program 3-Computer Science and Engineering	15	15	19				
Electrical Engineering and Computer Science, VI-A (Cooperative)							
Program 1-Electrical Science and Engineering	-	5	4	12	-	-	30
Program 3-Computer Science and Engineering	-	6	3				
Materials Science and Engineering, III	22	6	9	52	-	4	93
Materials Science and Engineering, III-A	-	-	1	-	-	-	1
Materials Science and Engineering, III-B (Cooperative)	7	16	13	-	-	-	36
Mechanical Engineering, II	43	21	37	39	-	4	144
Mechanical Engineering, II-A	6	2	3	-	-	-	11
Mechanical Engineering, II-B (Internship)	-	8	8	-	-	-	16
Nuclear Engineering, XXII	1	1	-	17	-	-	19
Ocean Engineering, XIII	-	1	-	5	-	1	7
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	-	-	-	-
Naval Construction and Engineering, XIII-A	-	-	-	3	-	-	3
Ocean Systems Management, XIII-B	-	-	-	1	-	-	1
Center for Advanced Engineering Study, EN	-	-	-	-	-	-	-
Total	177	151	163	308	-	27	826

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE								
Economics, XIV	6	7	6	13	3	1	36	
Humanities, XXI	3	2	6	-	-	-	11	
Humanities and Engineering, XXI-E	-	2	5	-	-	-	7	
Humanities and Science, XXI-S	2	2	1	-	-	-	5	
Linguistics and Philosophy, XXIV	-	-	-	27	4	-	31	
Political Science, XVII	1	1	1	46	12	3	64	
Psychology, IX	4	5	7	13	-	-	29	
Total	16	19	26	99	19	4	183	
SLOAN SCHOOL OF MANAGEMENT								
Management, XV	11	14	8	83	3	4	123	
Management Fellows, XV-A	-	-	-	9	-	-	9	
Management-Operations Research, XV-B	-	-	-	4	-	-	4	
Management-Ph.D, XV-P	-	-	-	11	-	-	11	
Total	11	14	8	107	3	4	147	
SCHOOL OF SCIENCE								
Applied Biological Sciences, XX	-	-	-	48	1	-	49	
Biology, VII	40	27	29	44	-	1	141	
Biology, VII-A	1	-	6	-	-	-	7	
Biology, VII-B	7	6	8	-	-	-	21	
Biology, VII-W (Woods Hole)	-	-	-	12	-	-	12	
Chemistry, V	10	11	10	61	-	-	92	
Earth, Atmospheric, and Planetary Sciences, XII	7	6	2	25	1	1	42	
Earth, Atmospheric, and Planetary Sciences, XII-W (Woods Hole)	-	-	-	27	-	-	27	
Mathematics, XVIII	16	10	15	13	4	-	58	
Mathematics with Computer Science, XVIII-C	1	1	-	-	-	-	2	
Physics, VIII	11	11	15	37	1	-	75	
Physics, VIII-A	2	1	-	-	-	-	3	
Total	95	73	85	267	7	2	529	
Health Policy and Management, HPM								
Health Sciences and Technology, HST	-	-	-	2	-	-	2	
	-	-	-	10	-	10	20	
Undesignated	19	-	-	-	-	-	19	
First Year	290						290	
Grand Total	290	325	266	295	931	50	61	2,218

<sup>1</sup>Also included in Classification of Students  
Total undergraduate women 1,176; 11 special undergraduate women are included.

NUMBER OF DEGREES AWARDED IN SEPTEMBER 1985, FEBRUARY 1986, AND JUNE 1986

	S.B.			S.M.			M.ARCH. M.C.P.			ENGINEER			PH.D.			SC.D.			TOTAL		
	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E	S E P T	F E B	J U N E
<b>SCHOOL OF ARCHITECTURE AND PLANNING</b>																					
Architecture	-	-	-	-	-	-	1	10	29	-	-	-	-	2	2	-	-	-	1	12	31
Undesignated	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Architecture Studies	-	-	-	2	3	23	-	-	-	-	-	-	-	-	-	-	-	-	2	3	23
Art and Design	1	5	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	5	17
Planning	-	-	2	-	-	-	2	5	32	-	-	-	-	-	-	-	-	-	2	5	34
Real Estate Development	-	-	-	32	1	1	-	-	-	-	-	-	-	-	-	-	-	-	32	1	1
Urban Studies and Planning	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	2	2	2
Visual Studies	-	-	-	7	5	1	-	-	-	-	-	-	-	-	-	-	-	-	7	5	1
<b>TOTAL</b>	<b>1</b>	<b>6</b>	<b>20</b>	<b>41</b>	<b>9</b>	<b>25</b>	<b>3</b>	<b>15</b>	<b>61</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>2</b>	<b>4</b>	<b>4</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>47</b>	<b>34</b>	<b>110</b>
<b>SCHOOL OF ENGINEERING</b>																					
Aeronautics and Astronautics	1	7	73	18	20	30	-	-	-	1	-	-	3	4	3	2	-	3	25	31	109
Undesignated	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Ceramics	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4
Chemical Engineering	1	7	46	2	4	1	-	-	-	-	-	-	5	6	11	1	1	3	9	18	61
Undesignated	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Chemical Engineering Practice	-	-	-	5	14	7	-	-	-	-	-	-	-	-	-	-	-	-	5	14	7
Civil Engineering	-	1	22	10	11	24	-	-	-	-	1	2	5	7	4	-	2	1	15	22	53
Undesignated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Computer Science and Engineering	10	23	118	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	23	118
Electrical Engineering	28	29	216	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	29	216
Electrical Engineering and Computer Science	-	-	-	33	46	101	-	-	-	2	11	19	7	18	19	1	2	3	43	77	142
Electronic Materials	-	-	-	2	-	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3
Materials Engineering	-	-	-	1	-	6	-	-	-	-	-	-	-	-	-	-	-	-	1	-	6
Materials Science	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Materials Science and Engineering	1	4	40	-	-	-	-	-	-	-	-	-	11	10	10	1	2	1	13	16	51
Undesignated	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3
Mechanical Engineering	6	11	116	21	23	58	-	-	-	1	2	4	3	2	5	-	4	6	31	42	189
Undesignated	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Metallurgy	-	-	-	4	1	2	-	-	-	-	-	-	-	-	-	-	-	-	4	1	2
Naval Architecture and Marine Engineering	-	-	3	3	3	9	-	-	-	-	-	-	-	-	-	-	-	-	3	3	12
Nuclear Engineering	2	1	6	7	8	12	-	-	-	2	1	-	2	4	12	1	2	9	14	16	39
Ocean Engineering	-	-	6	4	3	8	-	-	-	1	1	6	2	1	1	-	1	-	7	6	21
Ocean Systems Management	-	-	-	3	2	1	-	-	-	-	-	-	-	-	-	-	-	-	3	2	1
Polymers	-	-	-	1	1	4	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4
<b>Total</b>	<b>50</b>	<b>84</b>	<b>671</b>	<b>114</b>	<b>137</b>	<b>272</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>7</b>	<b>16</b>	<b>31</b>	<b>38</b>	<b>52</b>	<b>65</b>	<b>6</b>	<b>14</b>	<b>26</b>	<b>215</b>	<b>303</b>	<b>1,065</b>

SCHOOL OF HUMANITIES AND SOCIAL SCIENCE																		
Cognitive Science	-	3	6	-	-	-	-	-	-	-	-	-	-	3	6			
Economics	1	1	18	1	-	1	-	-	-	6	9	10	-	8	29			
Humanities	-	2	5	-	-	-	-	-	-	-	-	-	-	2	5			
Humanities and Engineering	2	1	6	-	-	-	-	-	-	-	-	-	-	1	6			
Humanities and Science	-	-	6	-	-	-	-	-	-	-	-	-	-	-	6			
Linguistics	-	-	-	-	-	-	-	-	-	3	4	3	-	3	3			
Philosophy	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2			
Political Science	-	5	6	1	2	7	-	-	-	1	8	7	-	2	20			
Psychology	-	-	-	-	-	-	-	-	-	1	2	3	-	1	3			
Total				3	12	49	2	2	8	-	-	23	-	16	80			
SLOAN SCHOOL OF MANAGEMENT																		
MANAGEMENT	-	3	29	3	12	222	-	-	-	3	4	2	-	6	253			
SCHOOL OF SCIENCE																		
Applied Biological Sciences	-	-	-	-	-	-	-	-	-	5	4	4	-	5	6			
Biochemical Engineering	-	-	-	1	2	2	-	-	-	-	-	-	-	1	2			
Biology	-	-	-	-	-	-	-	-	-	8	5	7	-	8	7			
Undesignated	-	3	33	-	-	-	-	-	-	-	-	-	-	3	33			
Chemistry	-	4	38	1	-	1	-	-	-	9	13	16	-	10	55			
Earth and Planetary Sciences	-	-	-	2	1	3	-	-	-	-	-	-	-	2	3			
Earth, Atmospheric, and Planetary Sciences	-	1	8	-	-	-	-	-	-	3	9	6	-	3	14			
Life Sciences	2	7	61	-	-	-	-	-	-	-	-	-	-	2	61			
Mathematics	2	7	55	1	2	3	-	-	-	3	1	15	-	6	73			
Mathamatics with Computer Science	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2			
Meteorology	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1			
Neural and Endocrine Regulation	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-			
Nutritional Biochemistry and Metabolism	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-			
Oceanography	-	-	-	1	1	-	-	-	-	-	-	-	-	1	-			
Physics	5	9	66	3	3	4	-	-	-	13	16	20	-	21	90			
Toxicology	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-			
Total				9	31	263	10	11	14	-	-	68	-	60	347			
Health Sciences and Technology				-	-	-	-	-	-	1	1	2	-	1	2			
Management of Technology				-	-	24	-	-	-	-	-	-	-	-	24			
Operations Research	-	-	-	2	3	8	-	-	-	-	-	-	-	2	8			
Technology and Policy	-	-	-	4	1	13	-	-	-	-	-	-	-	4	13			
Transportation	-	-	-	4	4	4	-	-	-	-	-	-	-	4	4			
Without Course Specification	-	-	-	6	10	16	-	-	-	-	-	-	-	6	16			
Awarded Jointly with Woods Hole Oceanographic Institution																		
Biology	-	-	-	-	-	-	-	-	-	1	1	1	-	1	1			
Civil Engineering	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2			
Earth, Atmospheric, and Planetary Sciences	-	-	-	-	-	-	-	-	-	-	4	1	-	4	1			
Electrical Engineering and Computer Science	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-			
Mechanical Engineering	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1			
Ocean Engineering	-	-	-	-	-	-	-	-	-	-	1	-	1	1	1			
Grand Total				63	136	1,032	186	189	605	3	15	61	7	97	1,927			

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## Office of Sponsored Programs

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For fiscal year 1986, the total volume of sponsored research performed on campus approximated \$253,254,000, an increase of 4.8 percent over fiscal 1985 volume of \$241,725,000.

The 5.8 percent increase in the level of research funded by Federal sponsors reflected significantly different growth levels for individual agencies. Research sponsored by DOD and DHHS increased on the order of 13 percent over fiscal 1985, when they increased by close to 11 percent over 1984. The 9.3 percent increase in NSF support and 4.5 percent increase for NASA also represent modest increases over the growth in 1985.

In contrast, research funded by DOE declined by over three percent compared with an increase of over nine percent in 1985, and the support from all other Federal sponsors declined 11.7 percent following a decrease of 9.4 percent over 1985.

With respect to non-Federal sponsorship the rate of growth for industrial support has slowed to 8.5 percent in fiscal 1986 compared with 21 percent in 1985 and 40 percent in 1984; foundation support increased slightly compared with a small decline the previous year; and the reduction in support by state and local governments and by foreign sponsors has resulted in a decline of nearly 90 percent in other non-federal support.

### CAMPUS RESEARCH VOLUME BY SPONSOR

(in thousands of dollars)

	<u>1968</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>
Department of Defense (DOD)	17,285	19,183	23,011	27,429	31,883	34,626	38,578	43,418
Department of Energy (DOE)	9,841	50,004	49,562	46,283	48,271	51,489	56,363	54,511
Department of Health and Human Services (formerly DHEW)	7,843	25,320	29,175	30,911	30,870	36,324	40,252	45,735
National Aeronautics and Space, Administration (NASA)	6,170	9,295	10,525	11,053	10,445	11,888	12,315	12,864
National Science Foundation (NSF)	7,073	25,055	29,913	29,776	31,003	30,876	33,658	36,772
Other Federal Sponsors	1,711	9,554	10,211	11,811	10,400	9,783	8,863	7,823
<u>Total Federal Sponsorship</u>	<u>49,923</u>	<u>138,411</u>	<u>152,397</u>	<u>157,263</u>	<u>162,872</u>	<u>174,986</u>	<u>190,029</u>	<u>201,123</u>
Industry	2,148	13,058	17,164	19,695	19,753	27,686	33,456	36,290
Foundations and Other Nonprofits	3,159	9,654	11,614	11,699	13,196	15,743	15,282	15,532
Other	<u>598</u>	<u>1,999</u>	<u>1,795</u>	<u>3,313</u>	<u>3,452</u>	<u>3,166</u>	<u>2,958</u>	<u>309</u>
<u>Total Non-Federal</u>	<u>5,905</u>	<u>24,711</u>	<u>31,573</u>	<u>34,707</u>	<u>36,401</u>	<u>46,595</u>	<u>51,696</u>	<u>52,131</u>
Total Research Volume	<u>55,828</u>	<u>163,122</u>	<u>183,970</u>	<u>191,970</u>	<u>199,273</u>	<u>221,581</u>	<u>241,725</u>	<u>253,254</u>

## SIGNIFICANT DEVELOPMENTS

As in past years, a variety of continuing developments and new events had an impact on sponsored research programs. Among these were the following:

### Gramm-Rudman

The effect of the Gramm-Rudman Act on research funding in fiscal 1986 was to some extent moderated because of delays involved in its implementation. Nonetheless, in order to achieve a 4.3 percent cut in the government fiscal year ending September 30, 1986, a number of agencies reduced awards made in the spring and thereafter by greater amounts, most commonly in the 8 - 12 percent range, with some agencies applying cuts across the board and others applying them selectively. A more significant impact is anticipated for fiscal 1987 and, in addition to their broad concerns over the level of support for basic research, some universities have expressed alarm over the manner in which individual agencies intend to achieve the required reductions. Depending on the level of appropriations in fiscal 1987, NSF, for example, intends to consider the elimination of principal investigator salary support, limiting indirect costs reimbursement, and imposing larger cost-sharing requirements.

### Export Controls and Critical Technology

Last year we reported that DOD had adopted a policy stipulating that classification is the only national security restriction which may be placed on the conduct or reporting of fundamental research funded by DOD. That policy has to a large extent resolved some of the difficulties encountered with attempts to impose contract restrictions on publications and on the employment of foreign nationals on DOD funded research. Since then, the Department of Commerce has published for comment a proposed revision to the Export Administration Regulations which would similarly exempt fundamental research from export control restrictions. If the final regulations retain the principal features of those issued for comment, it will be another major step in limiting the application of restrictions on scientific communications.

### Strategic Defense Initiative

We noted last year that defense officials had given assurances that "Star Wars" projects at universities would be handled as fundamental research and, consequently, without restrictions on the dissemination of results. Concern remained, nonetheless, that there might be mid-course corrections resulting in classification or other controls. At the close of fiscal 1986, MIT had received six contract awards for on-campus research identified as part of the Strategic Defense Initiative program. These awards are being treated as fundamental research and represent an annual funding level of approximately \$1.5 million.

### Technology Licensing

During the year, the ad hoc Faculty Committee on Technology Transfer appointed by the Provost reviewed the operation of the MIT Patent, Copyright and Licensing Office as well as MIT technology transfer policies and procedures. Assisted by the director of technology licensing at Stanford University, who spent the year on leave at MIT, the committee recommended significant changes in MIT's approach to intellectual and tangible property resulting from its research programs and to the transfer of technology. These recommendations are currently being implemented, including the conversion of the patent office to the Technology Licensing Office under a new director, and the development of a comprehensive "creative products" policy applicable to all forms of intellectual as well as tangible research property.

### Federal Patent and Rights-in-Data Policy

Recent Federal patent legislation resulted in the issuance of new patent regulations applicable, to university and other non-profit contractors, at the close of the year. They contain further improvements to existing regulations which provide that universities may elect to retain title to inventions resulting from Federally funded research. They also extend this option to government-owned, contractor-operated facilities such as Lincoln Laboratory.

However, Federal regulations dealing with rights, including copyrights, in data generated during Federally funded research were still under review at year end. It is not yet clear the extent to which they will provide the presumption of ownership by the universities performing that research since several agencies still wish to control the ownership and distribution of software and other research results.

#### Fixed Allowance for Departmental Administration

As noted last year, in order to contain what it perceives to be the excessive growth of indirect costs charged to its research grants, NIH has for several years unsuccessfully proposed language in appropriations bills that would limit the payment of indirect costs on NIH grants to less than that otherwise allowable under Federal cost principles. During the past year, NIH collaborated with the Office of Management and Budget in proposing a revision to the Federal cost principle that would establish a fixed ceiling on reimbursement of indirect costs for administrative functions. This would have significantly reduced indirect cost reimbursement at universities, including, for example, a reduction at MIT estimated to exceed \$2 million dollars in fiscal 1987. After prolonged negotiation with university representatives, OMB was reportedly at year-end considering a substitute formula which would limit the reimbursement of indirect costs for the administrative effort of faculty and department heads to a fixed percentage of total direct costs.

#### Personnel Changes

During the year the following changes occurred in the Office of Sponsored Programs: Joan T. Kyhos left her position as assistant director on September 30, 1985, to accept a similar position at Harvard University; on November 1, 1985, John G. Mahoney transferred from assistant director of Purchasing to assistant director in OSP; Sandra Buford, formerly with the Wang Laboratories as senior compensation analyst, joined OSP as an assistant director on September 16, 1985; and Merrily Sterns, an assistant director, left OSP on June 20, 1986, to accept an appointment as senior assistant director in the Office for Sponsored Research at Harvard University.

GEORGE H. DUMMER



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## Senior Vice President

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This year, two major capital projects were completed; The Jerome and Laya Wiesner Building and the Microsystems Technology Laboratory. In addition, a program to renovate the Institute parking garages was completed as was one of our most successful projects with respect to its environmental impact, namely, landscaping of the area around the East Campus Dormitories and Walker Memorial.

During the year, a far-reaching decision was made to request proposals from several food service management companies to manage and operate all of the food service facilities on campus. A committee was formed to evaluate the proposals received and to recommend a management company. ARA Services, Inc., a recognized leader in the field, was ultimately selected and will be on board early next year.

A significant achievement during the year was the development of a strategic plan for MIT's administrative information systems. Implementation of this plan has begun and will continue over the next several years. Another major undertaking will be the replacement of MIT's present Centrex and Dorm Line systems with a new 5ESS digital switching or PBX system. MIT and AT&T-Information Systems entered into an agreement this year to effect this change and the new system should be in service in June of 1988.

Following are individual department reports.

WILLIAM R. DICKSON

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## Campus Activities Complex

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The ongoing Transition Project within the Campus Activities Complex (CAC) continued to make progress.

In anticipation of the relocation of the Tech Coop to Kendall Square, a major study was undertaken to assess the feasibility of redeveloping the commercial, dining, and meeting spaces in the Stratton Center. The study, conducted by Spaulding and Company, indicated that significant improvements in retail services, dining experiences, and meeting spaces could be achieved by funding renovations from the income to be derived from proposed retail leases.

A project team was appointed to begin detailed program development. Proposals were received from marketing/merchandising professionals and letters of interest were requested from design professionals. The planning and design process will continue next year with construction expected to commence in early 1988.

In other areas, the Transition Project provided for the achievement of several objectives including: the consolidation of support staff resources among the Stratton Center Activities, Operations, and Physical Plant Offices to provide greater effectiveness and efficiency; the initiation of an office data base and a computerized facilities/events scheduling system with full implementation expected later on this summer; and the commissioning of a lighting and acoustical study at Kresge Auditorium in view of the need for substantial modernization of the auditorium's systems. Effective July 1, 1986, supervision for staff, supporting facilities, and events in the CAC will be transferred to this office from Physical Plant.

STEPHEN D. IMMERMANN

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## Campus Police

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The Campus Police continued to provide 24-hour professional and emergency medical services to members of the MIT community. There were a total of 2,584 complaints received by the department this year. Of these, only 17 were in the crimes against persons category, a 22 percent decrease from last year and the lowest figure in 15 years.

As in recent years, larceny continued to be the most frequently committed crime on campus. Institute property losses totaled \$83,381, a decrease of 17 percent from last year; personal property losses totaled \$31,241, a decrease of 4 percent from last year; and residence hall losses totaled \$32,464, a decrease of 11 percent.

There were 21 vehicles stolen from MIT property, a 30 percent decrease from last year. This is the lowest number ever recorded since crime statistics were first published in 1970.

For the first time in several years, emergency medical service runs decreased. A total of 2,702 runs, including emergencies, transfers, and medical shuttles were performed throughout the year. This is a decrease of 11 percent from last year's figure.

A total of 10,376 escorts were provided during the year, a decrease of 11 percent.

JAMES OLIVIERI

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## Endicott House

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Although overall activity increased over the previous year, revenues were somewhat less than projected as a result of less residential business than anticipated. To counteract this trend, several policy changes were adopted during the year in order to encourage residential use and ultimately improve the business mix.

An operational study was conducted by the firm of Laventhol & Horwath, specialists in the hotel and conference center business. This study included an overall review of operations, as well as an analysis of our rate structure as compared with other conference facilities. As a result of this study, rates have been adjusted and some of the operational changes recommended have been implemented while others are under consideration.

Endicott House continues to be utilized by groups from within MIT as well as from outside the Institute. Through 11 months, the facilities were used 241 days and 179 nights by 144 groups. Of these groups, 57 were from MIT and 87 were non-MIT related. There were 29 resident groups ranging from an overnight stay to the nine-week Senior Executive Program. Of the resident groups, 12 were from MIT.

Overall, more than 10,000 people attended functions. Better than 28,000 meals were served and 6,500 room nights were utilized.

HOWARD F. MILLER

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## Graphic Arts and Audio Visual Services

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Total overall income at Graphic Arts increased significantly this year. For the first time, gross revenues exceeded \$5 million, representing a 14 percent increase over last year. The largest departmental increase occurred in the Institute copier program. Seventeen new copiers were purchased and rented out to various departments. A total of 43 copiers are now being administered by Graphic Arts. The volume of work in the copy centers also increased substantially.

Rental of video equipment in the Audio-Visual department showed a significant increase. Beginning on July 1, 1986, a new video production service will be offered as an added service to the community. The goal for this new service is to have it be a self-supporting operation. A two-year trial period is scheduled to explore its potential.

A new post, Manager of Customer Relations and Services, was established. This position will enable us to fill a long-felt need for better liaison between the various Graphic Arts departments and our customers.

JAMES W. COLEMAN

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## Housing and Food Services

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During the year, a decision was made to solicit proposals from several food service management companies for managing and operating all of the food service facilities on campus. A 12-member committee was formed to evaluate the proposals received and to recommend a management company. ARA Services, Inc., a recognized leader in the field, was ultimately selected. All hourly and support staff will be afforded the opportunity of becoming employees of the new company. We look forward with great anticipation to this association and we are confident that our campus food services will greatly benefit from this change.

Again this year, the modernization and maintenance of our facilities was of high priority. In addition to ongoing work such as painting and minor renovations which are carried out throughout the academic year, several major projects totaling \$1.4 million in costs were completed during the summer months. These projects included internal restoration and major exterior repairs at Senior House, the installation of new bathrooms in Bemis and Goodale, and the renovation of Talbot Lounge in East Campus. In addition, the area between and surrounding the East Campus dormitories was landscaped by installing flower beds and by planting additional trees and shrubs. A volley ball court was also installed for the students and benches were situated in the area giving pedestrians the opportunity to relax and enjoy the new surroundings.

Renovations geared to the combining of the Faculty Club kitchens into a single kitchen on the sixth floor were completed over the summer. Full-scale renovation of the Club, previously scheduled for next year, has been postponed until the summer of 1987 to permit the new management company to participate in the planning and design process.

The department was honored by having two of its members -- Albertina Alves, a cashier at Baker House, and Frank Pieciul, maintenance mechanic at West Campus Houses, receive The Murphy Award.

HARMON E. BRAMMER

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## Information Systems

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Activities within the Information Systems (IS) group continued at a rapid pace during the 1985-86 year. Among the more significant and far-reaching was the development of a strategic plan for MIT's administrative information systems. This plan, which was developed with the assistance of outside consultants and with the involvement of administrators from across the Institute, presents a coherent strategy for addressing the use of information technologies in support of the administrative and business activities of the Institute. Implementation of the plan is now underway with the initiation of several pilot projects.

Broadly speaking, the plan calls for movement towards a coordinated administrative computing environment where information in the Institute's central business databases is made available electronically to authorized individuals throughout the Institute and where the input data for these databases is captured electronically at the earliest possible point. The technology base for this new computing environment will consist of a reliable, secure, and auditable campus-wide computer network supporting a standardized set of locally controlled workstations, central mainframes, and software tools.

Fulfilling this vision will require continued evolution of our hardware and software systems over the next five years. But, less obviously and perhaps more importantly, it will require significantly more training for the Institute's staff, continued development of a service orientation within IS, creation of an Institute-wide set of policies and procedures governing such areas as data access, and successful alignment of roles and responsibilities between IS, central administrative departments, laboratories and academic departments.

Other major events for the year within IS include the decision to replace the present Centrex and Dorm Line telephone systems with an AT&T Information Systems 5ESS digital switch; the publication of "i/s", a periodic insert to Tech Talk, which provides news about information systems activities throughout the Institute; major changes in the Institute's central computing environment; and the continued development of the campus computer network. These activities are described more fully in the divisional reports which follow.

JAMES D. BRUCE  
CECILIA R. d'OLIVEIRA

### ADMINISTRATIVE SYSTEMS

Projects in Administrative Systems (AS) this year covered a broad spectrum of technologies, clientele, and activities. Evaluation and implementation of a range of applications on both microcomputers and mainframes in a variety of operating, database management, networking, and program language environments were supported. Included were standalone microcomputing applications for functions such as rooms scheduling and keys management; mainframe development for Life Income Fund Management, General Ledger, and Financial Reporting Systems, the Student and Voucher Payroll, and Reunion Gift Solicitation. Significant milestones were reached in the Pension Accounting and the Budget System projects. Opportunities to link mainframe data to microcomputing applications were explored in several activities.

The broad spectrum of the year's activities is also evident in the clients with whom AS worked and in the range of our activities. Some examples are needs assessment studies for Resource Development, for departments using student related data, and for central offices supporting the graduate admissions process; product evaluations of software packages supporting Physical Plant maintenance management, Telecommunications Systems management, and West Campus event scheduling; conversions to turnkey systems or services for the Credit Union and for Student Loans processing; enhanced support for production databases with increased security and improved functionality of fourth generation programming languages; and improved human interfaces for applications by incorporating guidelines for screen and report design into the development process and by increased attention to help facilities and other online documentation.

Exceptional efforts by clients and staff led to the shutdown in December 1985 of the 370/148 computer in the Ford Building with applications moving to IBM and DEC computers in the W91 main operations facility. The 370/148 represented a remnant of the past: vital business applications running in an outdated systems environment that were costly to operate and nearly impossible to maintain.

AS staff participated heavily in the data gathering efforts underpinning the Institute's Strategic Plan for Administrative Information Systems and have been involved in efforts to get the plan underway. The key to the Plan's success — broad participation and leadership from the community — is off to a strong start in the early programs. Technical support for the Plan's implementation will continue to be a significant portion of the AS workload in the coming year. Serious attention will also be devoted to changing the AS focus and style toward a team spirited, service oriented approach and to encouraging the distribution of information systems support skills throughout the administrative community.

MARILYN A. McMILLAN

#### INFORMATION SERVICES

This has been a year of expansion for Information Services. Activities include increased support of campus-wide computing, including personal computers; development of new publications and seminars; stronger support of Project Athena; and increased access to qualify software through coordination of site licensing. Information Services has also started to assume its role in the Strategic Plan for Administrative Information Systems by developing a training facility and providing additional support services.

The Microcomputer Center, in its second year, continues to grow. In response to customer interest, the Center expanded its hours and will extend them further in the coming year. New systems offered include the IBM PC-XT and AT, the new IBM Convertible laptop, and the Apple Macintosh Plus. Also available are computer software supplies, supplies and peripheral devices. Software not carried in stock may now be special ordered at prices well below list. Plans include expanding the range of peripherals and software offered. A LaserWriter Print Service is now available to Apple Macintosh users providing high-quality printed output, including graphics, from diskettes. This service is especially popular with students producing reports, theses, and resumes. Center consultants work closely with the Operations and Systems PC' maintenance group to provide maintenance of Apple and IBM systems.

Training Services is a new Information Services group. In addition to expanding participation in our existing computer systems and language courses, they provide hands-on training on IBM PCs and associated software programs, such as Lotus 1-2-3, and on DECmates. Training Services also initiated a lunchtime seminar series held daily throughout April. Sessions covering a wide range of topics were presented by staff from IS, other departments at MIT, and outside vendors with participation by over 600 members of the Institute community. A similar series will be offered throughout the coming year.

Consulting Services expanded its support of users of computer systems ranging from personal computers to mainframes. The staff evaluated personal computer software gaining expertise to assist the MIT community in selecting appropriate software for their application needs. Consulting Services continued to provide instructors, seminar leaders, and logistical support to training activities, and now provides additional software support and develops training in conjunction with Project Athena staff, especially in the area of computer graphics.

The scope of Information Services publications continues to expand. Last summer, Publication Services published Networks at MIT, a guide to the major computer network connections within MIT and beyond, and their use for communication by electronic mail and other applications. A new Guide to Information Systems describes services available from all four branches of IS. Also, Publications Services inaugurated the new periodical i/s, published as an insert to Tech Talk, to keep the MIT community up to date on information systems happenings throughout the Institute; i/s begins monthly publication in the Fall. Publication Services continues to work with Project Athena to produce several new documents describing Athena and its services.

RICHARD D. SCOTT

#### OPERATIONS AND SYSTEMS

Early in the year Operations and Systems completed the conversion to the new IBM processors and disks begun in April 1985. As a result we have approximately twice the computing power and disk capacity as we



did with the previous processors in less physical space and at the same annual cost. We also installed a Floating Point Systems 164 processor for highspeed (11 MFLOPS) array processing; two new IBM 4245 printers allowing us increased functions and better reliability for less cost, IBM 7171 communications controllers on both of the administrative IBM machines to allow controlled dialup and asynchronous access to these machines. Finally, the transfer of functions off the IBM 370/148 in E19 and this machine's shut down were completed in December 1985.

With Honeywell's announcement that they intend to discontinue offering Multics, we have decided to terminate that service at MIT on December 31, 1987. Multics has been available as a service since 1969 and its discontinuance will be traumatic for many of its users. All divisions of IS are working with the users to assist in migration to other systems.

During the year Operations and Systems installed a major new release of VM/SP (Release 4) on its three processors. Also installed were routine updates to the compilers and other products on these machines as well as several new products such as IBM EXPERT (to be used as a prototype for benefits analysis), 20/20 (an integrated spreadsheet program, GDDM (a graphical support systems), and XMENU/E (a forms and menu generator). A new security package, VMSECURE, will replace a number of local modifications as well as providing increased security.

The DEC systems were upgraded to VAX/VMS 4.3; all compilers and other products received updates as well.

Operations & Systems has continued to have operational and systems programming responsibilities for Project Athena. New facilities were installed in buildings 1, 4, 6, 16, 37 and E51. We are working with Project Athena to plan for the conversion of all public clusters to workstations as well as to begin to deploy machines to the living groups. By the end of the coming year some 800 Athena workstations are expected to be deployed.

We have started to extend our services to other groups as well. We were contracted by LCS to upgrade their IBM disks and to install a new IBM 5080 graphics system; and have installed MicroVAX systems for several clients. We are also moving the ILO VAX 11/780 to W91 under a facilities management agreement.

The PC Support Facility is in full operation with IBM and APPLE computers and we are starting to get involved in the DEC Microvax area. During the past year some 500 machines were serviced.

ROGER A. ROACH

#### TELECOMMUNICATIONS SYSTEMS

MIT and AT&T-Information Systems (AT&T-IS) have entered into an agreement under which AT&T-IS is to engineer, furnish and install a 5ESS switching system or PBX on the MIT campus. This system will replace MIT's present Centrex and Dorm Line systems and is scheduled to be in service June 11, 1988.

The 5ESS will introduce a wide and flexible range of features to end-users and will be driven by software (5E4) which will bring Integrated Services Digital Network (ISDN) capability to MIT. ISDN will provide a capability of end-to-end digital switched services and connectivity for offices and laboratories throughout the campus. The 5ESS/5E4 system in the PBX configuration to be installed at MIT is the first such system ordered from AT&T-IS in the country.

As part of the introduction of the 5ESS into the MIT telecommunications operations, a new universal interior wiring scheme will be installed. This scheme provides for two 4-pair wires terminating on two modular jacks. One will be used for switched telecommunications services via the 5ESS, and the other for non-switched applications, such as local area networks (LANs).

Gateways to the campus computer network have been installed in 19 different building locations, enabling Project Athena, departmental and laboratory computer users to share resources, transfer files, etc. In addition, a number of departmental LANs were installed on a contract basis. T-1 facilities became operative between Harvard, Brown and MIT, and between MIT and the John von Neumann Center supercomputer facility in Princeton, NJ.

In FY1987 the campus computer network will be further extended throughout the campus. In order to facilitate that expansion, as well as the 5ESS interbuilding cabling, the MIT underground telephone duct system will be enhanced and expanded to add additional duct space and to connect to a number of buildings adjoining the campus.

The campus computer network, a token ring network running at 10 Mb/s, is the largest Proteon network in operation in the country. Network redesign plans are underway for FY1987 with plans for the data rate to be increased to approximately 100 Mb/s at a future date.

Academic course material is now transmitted over a dedicated microwave facility between MIT and the Woods Hole Oceanographic Institute. Tie lines interconnecting the respective institutional telecommunications systems have been migrated over to the facility from wire facilities previously provided by the local exchange carrier.

The MIT long distance network has been reconfigured, with a decreased dependence on satellite facilities for telephone calls to distant parts of the country.

In line with the decision to replace the Dorm Line system with the 5ESS, action was initiated to minimize the costs to the Institute and the students. This action included seeking state regulatory approval of flat rate residential local exchange network facilities for use by MIT students through the 5ESS. That approval is currently pending regulatory resolution.

MORTON BERLAN

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## Office of Facilities Management Systems

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In a recent article entitled "Encouraging Technology Transfer", President Gray stated that "Creative thought does not in itself ensure the transfer of discoveries to society in a meaningful way. It is therefore essential that we develop cooperative activities between basic research institutions and industry that will assure both the rapid and effective transfer of new technologies and the necessary financial support of the underlying research." These 'cooperative activities' have been the core of this year's achievements by the Office of Facilities Management Systems (OFMS).

In 1970 OFMS pioneered the development of INSITE, facilities management software designed primarily as a space accounting system for MIT. OFMS is responsible for the auditing of MIT's physical space, complete with floor plans, and for maintaining a current inventory on its database. Reports on this detailed accounting system as well as reproductions of MIT's scaled floor plans are available to academic departments and administrative offices upon request.

Since 1973 MIT has shared the technology through a consortium of INSITE users representing academic, healthcare, corporate, and government institutions. In addition, the consortium encourages the exchange of ideas and experiences on facilities management systems. Consortium members continue to develop various uses of INSITE such as grants tracking, equipment inventory and maintenance, analysis and planning. This year's new consortium members are: the Universities of Arkansas and Massachusetts (Amherst), Vanderbilt University Campus Planning Office and Grants Accounting Office, and the Good Samaritan Hospital in Portland, Oregon. Personnel from these institutions attended INSITE training classes at MIT/OFMS. Applications coordinators, as well as the director, maintain direct contact with INSITE users, responding immediately to requests for assistance both on the telephone and through a visit to the member institution.

Another 'cooperative activity' this year was the implementation of an OFMS-designed CAD system, developed under a grant from the Atlantic-Richfield Company of Los Angeles. The CAD system, which links to INSITE, operates on an IBM PC/AT and is used to digitize and display floor plans, provide graphic response to queries on INSITE data, and incorporate changes to the INSITE database. The INSITE-CAD system is already in use at the Universities of Syracuse, Alaska, and McMaster (Canada), CUNY, the Good Samaritan Hospital, and MIT. Personnel from these institutions attended INSITE-CAD training classes at MIT/OFMS.

Other examples of industrial support for OFMS research this year include donations of software and telecommunications equipment from Microvector, Inc. of Armonk, New York, and Northern Telecom, Inc. of Nashville, Tennessee. Such generous contributions enhance our continuous systems design and programming efforts.

There is a serious demand for facilities management educational offerings. To meet it, the course 'Facilities Management for Senior Executives' will be given twice this year in response to the oversubscription of the fall program. This year's conference and workshops will enable participants to see the INSITE CAD and Query systems in operation. The publication of the quarterly journal continues. And, finally, the Director of OFMS has maintained his active lecture schedule, appearing at conferences across the country and speaking on the following topics:

- Academic research facilities as a national resource;
- Managing real estate assets by computer;
- Cost allocation for use of equipment in research;
- Organizational strategies for facilities management functions;
- Flexible high-tech facilities database analyses.

KREON L. CYROS

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## Physical Plant Department

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The dramatic drop in the price of oil, from \$30/barrel to \$13.50 had a major impact on the Physical Plant budget, resulting in a projected \$2.1 million reduction in Institute energy costs for the year. While this temporary respite makes conservation pay-backs longer, we continue to explore ways for further reducing energy use in anticipation of the future.

Our efforts to develop an on-line management information system have been delayed due to higher than projected costs for vendor software customization. We are currently pursuing a mix of in-house and vendor supplied software in order to make better use of existing resources and to reduce potential costs.

### Facilities Construction and Renovation

The Arts and Media Technology Building was completed in the summer and dedicated in October as the Jerome and Laya Wiesner Building. Construction of the Experimental Media Facility in unfinished space in the building was started in late spring. This project consists of acoustic materials on the walls and ceilings, an access floor, and a travelling crane at one of the upper levels for positioning research equipment in the space. Completion of this facility is scheduled for early next winter.

The fitting out of the completed Microsystems Technology Laboratory on Vassar Street was completed in the spring and many of the laboratories in the facility are operational. During the year several studies were carried out for a proposed project to upgrade and expand the Rotch Library. As of the end of the year, no final decision among several options had been made. The high volume of space renovation projects continued including one completed in Building 20F for the Center for Space Research, a fermenter facility in Building 16, and work for the Ceramics Processing Research Laboratory in Building 12. Major space change projects are underway for Architecture in Building N52 and the Laboratory of Nuclear Science in Building 24. During the year a project to extend the central chilled water system to service the National Magnet Laboratory on the northwest campus was completed. A study to determine the feasibility and financial impact of cogeneration at MIT was completed in the spring and evaluation of issues of permitting, financing, and fuel availability continue. We consider this project a major opportunity for both Physical Plant and the community because of its potential role in countering increasing electricity costs.

### Building Operations

A program for modernization or rehabilitation of elevators continues with work initiated in Building 54, Building E52 and Building 56. The Building Operations group has been conducting a building by building facilities audit of all mechanical and electrical equipment in order to identify critical items requiring major maintenance. Personal computers have been introduced into the Central Utilities Plant, the Preventive Maintenance Office, the various Managers' offices and the Operations Center, in order to provide more comprehensive budgeting and management information. A major effort is necessary to integrate both the Microsystems Technology Laboratory (Building 39) and the Wiesner Building (Building E15) into day to day operations. The former includes a number of sophisticated water purification, waste water treatment, and hazardous materials detection devices not found in other existing laboratory buildings.

### Support Services and Building Maintenance

A major program for the restoration of the parking garages was completed with minimal disruption in the provision of parking resources for the community. Substantial efforts were made in painting and roofing to reduce a backlog of outstanding projects with approximately \$650,000 being expended.

Projects were carried out to replace the badly deteriorating Stratton Student Center main steps and part of the Kresge brick plaza. Plans were prepared for renovation of the Hermann Building Plaza and the front steps of the Massachusetts Avenue entrance with work to be carried out this summer. An agreement was reached with the new West Campus facilities group headed by Stephen Immerman to transfer responsibility for operation of Kresge and the Stratton and Chapel buildings from Physical Plant to this new group. This will involve a transfer of up to 20 administrative staff and service personnel.

PAUL F. BARRETT

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## Planning Office

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The Planning Office's activities this year reflect the continued effort to strengthen our institutional research and planning resources, while continuing to provide the Institute with a strong physical planning and community planning capability.

### INSTITUTIONAL RESEARCH

This year a major effort was invested in the development of a management information and planning system. Phase one of the management information system project was begun and it shows early promise of being a valuable resource for MIT. A Fact Book of selected statistics summarizing the principle indicators of institutional growth and change was produced for senior officers and members of the MIT Corporation and will be available as a standard reference in the future. Continuing efforts on an analysis of historical space use among MIT departments are being made.

A number of management studies, reports and the development of new planning tools were completed this year. They included an analysis of MIT's conference activity, the production of the Cross Registration and Faculty Housing reports, support for the Graduate Student Council's Housing Survey, assistance to the Faculty Policy Committee's Subcommittee on Housing, the development of an Enrollment and Resource Planning model, support for the Institute's parking allocation system, and responses to requests for data from national agencies, local government, and other universities.

Ongoing efforts of the institutional research staff include participation in the administrative systems pilot study on the MIT employee data base, continued development of planning data base systems, and the preliminary development of an executive information system.

### PHYSICAL PLANNING

We have begun a major review of our Capital Development Program in anticipation of the Campaign for MIT. Reflecting a strong interest in housing, a site study for graduate student, faculty, and staff housing was begun in the late spring of this year. A review of transportation and parking policies was completed and a street improvements plan is under way. Efforts to improve the MIT landscape environment continues with the completion of the Walker Memorial pedestrian way, the East Campus Houses landscape, and the class of 1985 Senior Gift at the head of Amherst Alley. In connection with future land needs, a report and presentation was prepared for the Provost on MIT's land resource requirements.

### COMMUNITY PLANNING

Events in Cambridge required our attention and coordinating efforts throughout this year. The completion of major elements of the Kendall Square urban renewal project including: substantial completion of the new hotel, the new subway station, the relocation of the Tech Coop, and a redesigned Main Street will all make a major difference in the Institute's immediate environment.

The Simplex Project and Cambridgeport continue to be a major subject of our attention. This year the submission of an environmental impact statement by Forest City Enterprises, the University Park Developers, required careful evaluation of the impact of this project, in which MIT is deeply involved, on the Institute itself. We continue to monitor the Massachusetts Avenue and Harvard Bridge projects as well as the many zoning and land use policy issues raised by community groups in Cambridge.

O. ROBERT SIMHA

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## Safety Office

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The Safety Office quarters in the Ford Building were completely renovated this year enabling the staff to work in a much more efficient environment.

### Education and Training

Implementation of "Right to Know" training programs was a major activity. Typical of these efforts was the establishment of formal safety training programs in the School of Science and the Plasma Fusion Center. Development of Institute-wide Emergency Action Plans continued throughout the year. The Safety Office has reviewed over 40 programs, and, to date, nine have been completed and approved.

### Hazardous Materials

The regulation of hazardous materials continues to receive much attention from Federal, State, and local agencies. During the past year, we were required to prepare and implement a contingency plan designed to prevent and minimize hazards to public health, safety, or welfare of the environment from fires, explosions, spills, etc., in facilities where hazardous waste materials are stored; register with governing agencies the location of underground tanks storing hazardous materials and comply with the regulations to ascertain, on a day-to-day basis, tank integrity against leaking; remove underground storage tanks that have been abandoned or out of service for six months or more; and comply with a local ordinance prohibiting experimentation with certain chemical warfare-related nerve agents.

### Laboratory Safety

A compressed gas cylinder inventory control program initiated by the Purchasing Office has become an invaluable aid in tracking hazardous gases on a room-by-room basis.

The volume of hazardous chemicals collected and shipped increased by about ten percent.

### Fire Protection

The installation of automatic sprinkler systems was completed in Building W85, Tang Hall, and Senior House. A fire safety project is currently underway at Endicott House including installation of a new fire alarm system, increased sprinkler protection, and the purchase and installation of an emergency electrical generator.

A new state law was recently passed requiring automatic sprinkler systems in high rise buildings. The Safety Office conducted a survey of the campus buildings to determine the potential costs of this law.

### Safety Audits

Annual inspections of the entire campus were conducted again this year by city building officials and representatives of our insurance carrier. Some departmental safety committees have implemented their own inspection programs. Also, a program was initiated in certain buildings to reduce the debris stored in corridors. This program met with only limited success and the Safety Office will continue this effort next year.

JOHN M. FRESINA

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## Vice President and Treasurer

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### INTRODUCTION

The amounts received from gifts, grants, bequests, and membership in the Industrial Liaison Program (ILP) totaled \$62.7 million and were exceeded only by the record results in the previous year. Although gifts and other support continued at a high level, many activities of the office were directed at preparing for the upcoming Campaign for MIT.

After eight years as vice president for resource development, Samuel A. Goldblith stepped down to assume a new position as Senior Advisor to the President. Professor Goldblith has been particularly successful in developing new sources of support from Japan and Europe, and we are fortunate his services will continue with primary focus on these areas. Beginning with his leadership as its director 12 years ago, the Industrial Liaison Program continued to expand. Total private gifts and industrial liaison support increased by 68 percent during his eight years as vice president.

Glenn P. Strehle, Treasurer, assumed the additional title of Vice President on March 1, with responsibility for resource development. He has been treasurer since 1975 and has been involved in the cultivation and solicitation of numerous important donors. He also has been responsible for the processing of gifts to the Institute through the recording secretary's office. Mr. Strehle expects to devote most of his time during the campaign to the management of resource development, and Allan S. Bufferd, Deputy Treasurer and Director of Investments, has assumed day-to-day responsibility for operations of the Treasurer's Office.

### PRIVATE SUPPORT

Private support for 1985-86 totaled \$62.8 million, including the following: \$54.8 million in gifts, grants, and bequests, and \$8 million in support through membership in the Industrial Liaison Program. The total compares with \$68.5 million in 1985, \$55.7 million in 1984, \$56.4 million in 1983, and \$46.6 million in 1982. Gifts-in-kind for the past year (principally gifts of equipment) were valued at \$8.3 million.

Sources of gifts for fiscal year 1986 were: alumni, \$14.8 million; non-alumni friends, \$4.6 million; corporations, corporate foundations, and trade associations, \$15.7 million; foundations and charitable trusts, \$19 million; and others, \$0.7 million. Included in the totals for alumni and friends are gifts of \$1.9 million made to the Rogers, MacLaurin, and Compton Pooled Income Funds. The total income of \$8 million for corporate liaison programs represents an 18 percent increase over the total for fiscal year 1985.

Donors designated expendable and endowed funds as follows: unrestricted, \$8.5 million; departments, \$20.6 million; faculty salaries, \$6.1 million; graduate student aid, \$5.4 million; undergraduate student aid, \$4.3 million; building construction funds, \$4.3 million; and other funds, \$5.6 million.

Included in the totals above was support for five new endowed chairs--three full professorships and two career development professorship.

### Campaign Preparations

The planning for the upcoming campaign was a major activity of the resource development staff. At the March 7 meeting of the Corporation, the Chairman and the President outlined the schedule for the campaign. This included the completion of campaign priorities in time for description at the October 3, 1986 Corporation meeting and the planned announcement of the campaign to the Corporation on March 6, 1987. The announcement to the public is expected to take place in Cambridge during the spring of 1987.

The overall goal of the campaign will include both gifts received following the campaign announcement and those received prior to the announcement from the Nucleus Fund. This fund includes all gifts received from January 1, 1986 and gifts to endowment and unrestricted funds included in the Advance Initiative from July 1, 1984 to December 31, 1985.

The short time available prior to the beginning of the campaign necessitated simultaneous activities in parallel that might have been performed in sequence. These activities include the setting of campaign priorities, screening of gift prospects, recruiting of volunteers, hiring and training of

staff, preparing campaign communications, installing information systems, and planning campaign activities. We are assisted in this process by the staff of Barnes & Roche, Inc. of Rosemont, Pennsylvania, fundraising consultants.

The Campaign Priorities Group under the leadership of Provost John M. Deutch began defining priorities for the campaign in September, 1985 and completed the major phase of this process in early July. These priorities are to be further defined by the central administration and the five schools and then reconciled with the fundraising expectations of the campaign.

The Corporation Campaign Committee under the leadership of Carl M. Mueller, a life member of the Corporation, is the senior volunteer organization. This committee includes Joseph G. Gavin, Jr., 1st President of the MIT Alumni Association for 1986-87, and D. Reid Weedon who was named Chairman of the National Campaign Committee in June. This committee will include the area chairmen and other key volunteers in 20 major markets.

The plan for campaign communications is being developed by Joseph G. Carr and Carr Associates of Cambridge in coordination with the Office of Communications in Resource Development. Similar planning for donor relations, donor recognition and campus visits is also underway. The campaign kickoff functions will be managed by Alice Tripp, who ably supervised these activities in the Leadership Campaign.

The campaign will require important staff additions, particularly of staff with experience in personal solicitation and cultivation of prospects. By year end, the searches were already initiated for most of the staff needed to serve the early stages of the campaign.

The needs of the campaign will require new ways to manage the overall effort and assure proper utilization of the efforts of both volunteers and staff. A particular need to make the resource development staff more accessible to faculty and volunteers is being achieved by combining various fundraising functions into user-oriented offices that can more easily interface with both solicitors and donors.

The planning and changes necessary to achieve the fundraising potential of the Institute were in full operation at year end and will continue well into the early stages of the post-announcement period.

#### DEVELOPMENT OFFICE

Under the direction of G. Rodger Crowe, the development office continued to provide prospect clearances, background information and advice on fundraising strategies, and priorities to senior officers, deans, school development officers and faculty. It also began support of new major campaign priorities such as "hazardous waste management" and "Leaders for the Manufacturing Industries." In the past year, the development office received clearance requests from the five schools for 268 prospects, of which 232, or 87 percent, were available for solicitation. In planning for the upcoming campaign, the development office also did a number of studies of historical cash flow from gifts and projections of future gift income. Rodger Crowe and John E. Oldham assumed expanded responsibilities for the management of major prospects and have provided support to Chairman David S. Saxon and President Paul E. Gray in the solicitation of members of the Corporation, the Corporation Development Committee and other major prospects for personal commitments prior to the public announcement of the campaign.

In further preparation for the campaign, seven additional people, including six at the support level, joined the research staff which has been divided into specialized groups. The Senior Officer Research Group, headed by Lois A. Graham, has met the expanding needs of senior officers by preparing detailed background summaries on prospects for a number of major fundraising trips. The Faculty/Staff Research Group, headed by Nancye J. Mims, provides similar support to school development officers, faculty, and several resource development staff members. Both groups now report to Associate Director Jack Oldham, as does the Prospect Control Group, which tracks approximately 800 corporate, foundation and individual major prospects and issues periodic prospect status reports.

The primary responsibility of the Prospect Identification Group, headed by Lindsey V. Humes, is the identification and evaluation of new prospects for the campaign. Working with Leadership Gifts staff and the school development officers, the group has begun to systematically review alumni and others identified as potential major prospects through the National Resources Screening Program and several other projects. For example, a list of 750 wealthy Americans sent to Corporation and Corporation Development Committee members identified approximately 380 people with MIT contacts, while an analysis of Eastern Massachusetts high technology companies showed 226 prominent alumni at 67 companies.



The Production Services Group, headed by Phyllis M. Gallant, is responsible for word processing, secretarial support, pledge status reports and pledge invoicing, and budget and personnel management.

#### Personnel Changes

Jack Oldham was promoted to Associate Director and Lindsey Humes was promoted to Assistant Director, both effective September 1, 1985. Nancye Mims and Lois Graham were both promoted to assistant director, effective February 1. Karen Engelbourg resigned to accept another development position at Brandeis University.

#### HEALTH SCIENCES

Barbara Gunderson Stowe, Director of Health Sciences Development, continued the health sciences fundraising activities while also assuming responsibility relating to several major gifts prospects. In April, she resigned to become Assistant Dean for Development in the School of Humanities and Social Science. She will continue to assist the Chairman, President and the Vice President and Treasurer with major gifts prospects.

#### COMMUNICATIONS

The Office of Communications, under the direction of Deborah J. Cohen, continued to produce several key publications, including the "Factual Profile," "CDC News," and "Perspectives on MIT." New pieces included an MIT folder, "Professorships at MIT" and "Teaching Firsts," a timeline of curriculum developments. In April, these publications were awarded a gold medal by the Council for the Advancement and Support of Education.

Donor relations activity concentrated on intensifying existing programs of stewardship, publicity, donor recognition, and donor outreach. In addition, during the spring the office assumed responsibility for inaugurating a major campus visits program, and designing events to launch the capital campaign.

#### Personnel Changes

During the year, Stacy E. Hynes resigned from the office of communications, and was replaced by Jane A. Steenstra from March to June 30. At year end, Ellen Hoffman was given a leave of absence and began a consulting arrangement with Carr Associates. In June, the office was joined by Richard P. Anthony, senior staff writer. Just prior to year end, Ms. Cohen announced her intention to resign in August and assume the position of Assistant Dean for Development in the School of Architecture and Planning. She has successfully served in the office of communications and its predecessor for 12 years, including the past six years as its director.

#### CORPORATION DEVELOPMENT COMMITTEE

Chairman David S. Saxon presided over the October 31 meeting of the Corporation Development Committee (CDC), marking the twenty-first year of operation for this alumni group. The meeting was attended by 63 members, plus special guests and many members of the MIT staff. Also participating in the meeting were Paul E. Gray, President, Glenn P. Strehle, Vice President and Treasurer, and Carl M. Mueller, Chairman of the Corporation Campaign Committee. Attention was focused on laying the foundations for the capital campaign, and the role of the volunteer in it.

A special award was given to Dr. James R. Killian, Jr. '26, Honorary Chairman of the Corporation, recognizing his "many significant contributions to the Institute's financial stability."

The Dalton Award was presented to Mr. Norman B. Leventhal '38, a member of the CDC since 1970 and a Corporation member since 1975. He was commended for his "extraordinary record of service to MIT."

During the year many members of the Committee were helpful in a wide range of activities supporting, nationally and internationally, the Institute's fundraising and campaign planning.

The death of two Honorary CDC members during this year is noted with deep regret: George N. Bunker '31 and John J. Wilson '29.

#### SPECIAL GIFTS

The major priorities during the year in special gifts were the continuing identification and evaluation of new prospects, developing a field organization for the capital campaign, and helping to establish more "MIT presence" in important parts of the country. These activities were headed by Nelson C. Lees, Director of Resource Development and Director of Special Gifts.

## Leadership Gifts

Director Neil W. Didriksen and the leadership gifts staff continued to work closely with volunteers in the identification, cultivation, and solicitation of gifts from individuals, with particular emphasis on preparation for the campaign. The addition of Marilyn K. Kuhar as district director for New England and of Nathaniel H. Mayes, Jr. as district director for the Midwest and the Southwest substantially expanded field activity. District Director Elaine M. Myrinx has been carrying out her recently assigned responsibility for coverage of the West Coast, and James N. Phinney continued his valuable services in Metropolitan New York.

Donald P. Severance fully retired on June 30, 1986 after 48 years of service. He had joined resource development in 1975 after service for 12 years as Executive Vice President of the Alumni Association. He has been a thoughtful adviser and his knowledge and friendship with thousands of MIT alumni have strengthened the Institute's resources.

Identification of alumni prospects for the capital campaign remained the primary focus for the leadership gifts staff. Working with Edith E. Nelson, Director of the MIT National Resources Program, the district directors helped organize gift potential rating sessions in Seattle, San Francisco, San Diego, Dallas, Detroit, Cleveland, Pittsburgh, New Jersey, New York, Hartford, New Hampshire, and Boston, each hosted by a key alumnus. Over 250 alumni attended these sessions. District directors personally contacted an additional 250 alumni who agreed to review a listing of 1,500 names at their offices or homes.

The national resources program generated information on the charitable gift capacity of 11,683 alumni by the end of the fiscal year. Ratings have been entered into its database for 18,711 individuals through the efforts of Gregory D. Whall and support staff. This data has allowed for the identification of 2,221 alumni with an average charitable gift rating of \$100,000 or above.

Evaluation of alumni with a six or seven figure gift potential has been the second priority for leadership gifts staff. This has included collaboration with many others, including Rodger Crowe, Lindsey Humes, and the staff of the development office, faculty from several departments, and alumni screeners and prospects around the country.

The organization of area campaign committees in 20 major markets has been the third priority for leadership gifts. District directors have developed plans for recruiting area chairpersons in Boston, New York, Dallas, San Francisco, and Chicago, with assistance from Donald Severance and in consultation with the Alumni Association. District directors have initiated efforts to identify potential leaders and define organizational strategies in the other major markets.

The Sustaining Fellows Program continued its mission to recognize, involve, and cultivate special Institute benefactors. Membership increased to 862; 619 life members and 243 annual members. Breene M. Kerr '51 continued his effective chairmanship, ably assisted by E. Barbara Lewis, Manager of the Sustaining Fellows Program. On Saturday, April 26, 1986, the Sustaining Fellows Program held a symposium in Cambridge, titled "Perspectives on the Work Economy," chaired by Professor Franco Modigliani, followed by a formal reception and dinner at the Meridien Hotel, Boston. Attending the symposium were 375 members and guests and 244 joined President Gray and Chairman Saxon for the black tie event that evening. In addition to this spring's gala, members in Los Angeles, Dallas, and Chicago attended luncheons with Dr. Saxon and selected faculty. Hosts for these events were Frank S. Wyle '41, Edward O. Vetter '42, and F. Richard Meyer '42.

## FOUNDATIONS AND CORPORATIONS

The Office of Foundations and Corporations continued in its second year of operation as a unit within resource development under the direction of Vincent C. DeBaun. Successful efforts were concentrated on both endowed and expendable support for financial aid grants and loan funds, junior faculty chairs, and equipment for research programs.

A major thrust through the past year was cultivation and in-depth stewardship attention to current and recent donors, relating their previous commitments to the larger objectives of the Institute's forthcoming campaign. When feasible, emphasis was placed on the advantages to both parties deriving from long-range capital funding.

Within the special focus of the National Business Committee (NBC), Mr. Robert L. Mitchell '47, Chairman from 1982 to 1986, resigned the position following his retirement as vice chairman of Celanese Corporation. We are grateful that Mr. Mitchell will continue as a member of the NBC, which he has served so effectively and to which he has provided vital leadership.

The NBC, directed by Robert Hagopian, continued to seek new corporate interactions with the Institute. Twenty-three approaches were made via NBC introductions for support of Sloan Sponsors,

The Innovation Center, The Construction Industry Affiliates Program, the Media Laboratory, and the Industrial Liaison Program. Four new ILP members and one Sloan Sponsors membership have resulted to date with decisions regarding most of the remainder still pending. Special attention was given to increasing Canadian participation in the ILP, with a prospect pool of varied corporate and governmental agencies in different stages of development.

### INFORMATION SYSTEMS

The information systems necessary to serve the expanded needs of the campaign are being planned by a core group of representatives of Resource Development, Alumni Association and the Treasurer's Office. Administrative Systems was completing a user needs assessment as year end approached, which will enable the effective enhancement of the Prospect Management Systems using the alumni/donor/development systems database (ADDS) (formerly known as the alumni/gifts database) on the IBM mainframe in information systems.

The Institute initiated plans for the decentralization and coordination of information systems activities during the year and assistants were named for the four administrative vice presidents. On July 1 Barbara A. Durland became Assistant to the Vice President and Treasurer for Information Systems, and Assistant to the Executive Vice President of the Alumni Association for Information Systems, and will coordinate these activities within these departments.

### INDUSTRIAL LIAISON

During the past year, the Industrial Liaison Program again posted new levels of membership and of service to companies and to MIT faculty and departments. Directed by Professor James M. Utterback, the Program showed a net gain of five paying members, and cash flow exceeded \$8 million. Total membership now stands at 310, of which 289 are paying members and 21 are affiliate members, based on major gifts to the Institute.

Highlights of the year included complete redesign of the Program's publications: "The MIT Report," "Directory of Current Research," and symposia series announcements. Two special meetings were held by the faculty committee, chaired by Professor Lawrence E. Susskind, one with policy contacts from selected member companies to review Liaison program services from the client's viewpoint; the other with Liaison officers to review successful new memberships and new members' reasons for joining the program.

### Member Services

Outstanding meetings were conducted jointly with the Media Laboratory on "Media Technologies;" with the Biotechnology Process Engineering Center on "Biotechnology Process Engineering;" with MIT's Mechanical Engineering Department on "Engineering Design at MIT: Meeting Industry's Needs;" with the Sloan School of Management and the U.S. Government Labor Department on "New Industrial Relations;" and with MIT's REMERGENCE Center on "REMERGENCE: Understanding Materials and Structures."

Other meetings were presented during the fall and spring semesters on a variety of new topics: "New Developments in Sensor Technology," "Recent Advances in VLSI," "Composite Materials," "Management in the 1990s," "Manufacturing in the 1990s," and "China's Modernization."

The Industrial Liaison Program also held its second formal series of international short courses. Each course was conducted over a two to four day period; topics included "Fermentation Technology" held in Germany; "Management of Research, Development and Technology-Based Innovation" held in Israel and in England; "Controlled Release Technology" held in France; "Automatic Speech Recognition" held in Italy; and "New Directions in Strategic Management" held in Sweden.

The program of dinners bringing together chief executives from member companies with MIT's senior officers and faculty was successfully expanded. A total of 72 company chairmen and presidents attended one of seven dinners held at Endicott House (4), or in London (2), or in Paris (1). Dr. David S. Saxon, Dr. Paul E. Gray, Professor Paul A. Samuelson, and Professor Lester C. Thurow were the featured MIT speakers.

### Program Organization

During the year, a fourth industry group was formed within the office, headed by Gary J. DesGroseilliers, to further develop MIT's relationship with government agencies and the service industry, such as banks, insurance firms, retailers, venture capital companies and publishers. The Liaison Program's communications, including the monthly "MIT Report," the annual "Directory of Current Research" at MIT, Symposia, videotapes, short courses and communications services were combined in a group headed by David R. Lampe.

### Organizational and Personnel Changes

In the Industrial Liaison Program, Thomas R. Moebus, who was previously assistant director, was named Associate Director. Peter N. Cerundolo was promoted to Assistant Director; Gary J. DesGroseilliers was promoted to Senior Liaison Officer; Susan I. Shansky was named manager of communications services; Junco Norton was appointed administrative officer. The following new officers were appointed: Norma E. Henderson, Anita D. Horton, John F. McNeil, Linda K. Smith, Laura M. Robinson, and Marie-Teresa Vander Sande. Jennifer Knapp-Stumpp returned from her leave of absence to direct the meetings and symposia office.

Also during the year, Janet K. Anderson resigned to accept a position with the Psychology Department at MIT; John F. McNeil resigned to accept a position at Data Resources/McGraw-Hill; Roger A. Samuel resigned to become Program Manager of the Management of the 1990s Program at the MIT Sloan School of Management; and Kay Tamaribuchi resigned to become Special Assistant to the Chairman of the MIT Corporation.

GLENN P. STREHLE

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# Alumni Association

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The Alumni Association thrives when volunteers and staff join toward a common goal, each bringing their special skills and each with energy and commitment to the task at hand. Time after time this year this combination produced stellar results. The Alumni Fund created yet another record of \$11,178,000 and almost 28,000 donors. The Board of Directors of the Association has begun a thorough revision of the Association's constitution and by-laws. The AdHoc Campaign Committee has helped us to shape the Association's role in the upcoming capital campaign. The Class of 1961, using 95 volunteer classmates raised in excess of \$2,174,000, the first 25th reunion class to raise over \$2 million.

Key volunteer leadership was an essential ingredient to our success. Exceptional were the efforts of E. Milton Bevington, Class of 1949, President of the Alumni Association for 1985-86; Peter Saint Germain, Class of 1948, Chairman of the Alumni Fund Board; Harris Weinstein, Class of 1956, Chairman of the AdHoc Campaign Committee, and the entire membership of the Board of Directors for their superb groundwork on constitutional revision. These volunteers were aided by the efforts of our hard-working and dedicated staff.

There were significant management changes in the Association staff. Webb Elkins, SL 83, was promoted to Director of Alumni Relations and Secretary of the Alumni Association. Barbara Durland was promoted to a new position, Assistant to the Executive Vice President of the Alumni Association and to the Vice President and Treasurer of MIT for information systems. Jonathan Schlefer was promoted to Managing Editor of Technology Review. Katherine Cochrane joined the staff as Administrative Officer reporting to the Executive Vice President.

## Alumni Relations

The National Alumni Conference was held in Cambridge at MIT this past year. A series of workshops were presented which were aimed at helping alumni in all of their volunteer roles. President Paul E. Gray '54 and his wife Priscilla, Honorary alumna, graced us with their presence. The program, "A Look at MIT's Research Centers" featured a panel led by Kenneth A. Smith '58, Vice President for Research. The panelists were Professor Ronald C. Davidson, Director, Plasma Fusion Laboratory; Professor Daniel Roos '61, Director, Center for Technology, Policy and Industrial Development; Professor Phillip Sharp, Director for Center for Cancer Research.

Technology Day, June 6, 1986, focused on The Media Laboratory at MIT. Professor Nicholas Negroponte '66, Director of the Media Laboratory was the moderator. Panelists were Alan C. Kay of Apple Computers Inc.; Professor Andrew B. Lippman from the Media Laboratory, and Loren Carpenter, Senior Scientist, Pixar, Inc. The panel entranced the audience with the impact of computers on movies and television as they change the basic tenets of the entertainment industry. Over 1200 people participated in the symposium and the T-Day luncheon program. As always, "Tech Night at the Pops" was a festive sellout.

Reunion programs brought over 1200 alumni and guests back to campus for four days of reminiscence and camaraderie. Alumni representing fourteen reunion classes, 1916 through 1981 were present. Activities took place both on campus and in locations such as the Ritz Carlton and a mansion in Gloucester.

The Alumni Council convened six times over the course of the past year, usually on the last Monday of the month. Guest speakers included Jay Forrester '45; the MIT Shakespeare Ensemble; Shaoul Ezekiel AA '68; David Baltimore LI '61; David Saxon '41; and Dimitri Antoniadis. Average attendance for the meetings was 105, which is a slight drop from past years. The Council also features a "Sponsor a Student" program, where alumni are encouraged to pay for students' attendance. This program was more successful than in years past, likely as a result of greater emphasis in the meeting notices.

AMITA (Association of MIT Alumnae) activities are varied and take place throughout the year. The highlight of AMITA's calendar is the annual conference, usually held in mid-March. This year's conference was entitled, "Women on the Pyramid: Power in Technical Careers," and was held on March 14 and 15. A total of 250 people attended.

Other AMITA activities over the year included: the Annual Senior Academic Award, conferred on two graduating women students; a Talbot House weekend retreat; a telethon for the AMITA Scholarship Fund; an annual meeting at Endicott House; a cocktail party for MIT alumnae in the Los Angeles area.

BAMIT (Black Alumni of MIT) has two regularly scheduled programs over the course of the year; one is its newsletter, published four times a year. The other is the annual Black Students' Conference on Science and Technology. Last year's conference was not as successfully planned. Attendance was minimal, with approximately 50 people participating. The conference traditionally opens with a 'career showcase', in which 25-30 companies send representatives to speak to students about prospective employment. Last year's showcase was successful in that there was a good turnout of representatives. Unfortunately, they felt that there were fewer students to speak with than they had hoped.

The Board of Directors approved the following recommendations of the Awards Committee:

Bronze Beaver Awards: Bill C. Booziotis, AR, Class of 1960; Henry F. Lippitt II, Class of 1936, Robert A. Muh, Class of 1959; H. DuBose Montgomery, Jr., Class of 1971; Charles H. Spaulding, Class of 1951; and John F. Taplin, Class of 1935.

The Harold E. Lobdell, Class of 1917 Distinguished Service Awards: Noel Bartlett, Class of 1960; Alan W. Burke, Class of 1920; Ernest M. Cohen, Class of 1964; Edgar P. Eaton, Jr., Class of 1944; Harbo P. Jensen, Class of 1974; Bruce Hartenbaum, Class of 1959; Leslie C. Hruby, GM Class of 1973; Wendyl A. Reis, Jr., Class of 1956; Thomas J. McCue, Class of 1929; William C. Morris, Class of 1960; Antonia Schuman, Class of 1958.

The George B. Morgan '20 Awards: Dwight Taylor, Class of 1926; Louis Stouse, Class of 1942; George Palo, Class of 1928, and R. Maurice Tripp, Class of 1948.

Presidential Citation Awards: MIT Club of Colorado Mini-College Weekend; MIT Enterprise Forum of the North west; MIT Class of 1960 25th Reunion Gift Committee; AMITA, IAP Activity, "Getting the Job You Want in Industry: A Woman's Guerilla Guide to the Pin-Striped World".

Honorary Membership in the Alumni Association: Professor Mildred S. Dresselhaus; Elizabeth J. Whittaker; Joseph S. Collins.

The following alumni were elected by national ballot to serve three-year terms on the National Selection Committee: Lionel Goldring, Class of 1950, District #3; Wendyl Reis, Class of 1956, District #8, and Samuel J. Losh, Class of 1954.

The National Selection Committee made the following selections for terms starting July 1, 1986:

Elected to the MIT Corporation: E. Milton Bevington, Class of 1949; Joe F. Moore, Class of 1952; Ernest U. Buckman, Class of 1946.

Elected President of the Alumni Association: Joseph G. Gavin, Jr., Class of 1942.

Elected Vice Presidents of the Alumni Association: H. DuBose Montgomery, Class of 1971, and Shirley A. Jackson, Class of 1967.

Elected Directors of the Alumni Association: Susan L. Kannenberg, Class of 1961, District #1, Charles E. Kolb, Jr., Class of 1967, District #2; Karen Arenson, Class of 1970, District #4, and Robert H. Morse, Class of 1963, District #5.

In the Alumni Relations area, Webb F. Elkins, SL '83, was promoted from Regional Director for the Midwest to Director of Alumni Relations and Secretary of the Alumni Association. The new Regional Director for the Midwest is Paul Leach. Eliza Dame was appointed Coordinator, Reunion Programs.

The MIT Enterprise Forum continued its growth. Organizing committee meetings took place in Pittsburgh, PA. and Beijing, China. Total operative forums now number ten. As growth leveled in some of the earlier established forums, maintenance and administrative objectives were given higher priority. A tracking and monitoring system of previous presentors, developed in Cambridge, will be applied nationally.

A seminar was given in Houston entitled "What Lessons Were Learned in Massachusetts". Leading the event were Paul E. Gray, Class of 1954, President of MIT; Sam Bodman, Class of 1965, President of Fidelity Management and Research Company; Ray Stata, President, Analog Devices, and George Kariotis (Massachusetts Governor's Office).

The annual Fall workshop featured Kenneth H. Olsen, Class of 1950, President of Digital Equipment Corporation. The theme was "Finance Options in Uncertain Times."

Student/alumni programs continued to grow. Programs involving seniors again centered on our successful Senior Dinners which continue to be held at the President's House through the enthusiastic and active participation of Dr. and Mrs. Gray. Many clubs work with the Educational Council in their local regions to sponsor meetings of applicants and students during the various stages of the MIT admissions application process.

The Undergraduate Research Opportunity Program supplied three student speakers for club events. Two were sent to Minneapolis and one to Cleveland. Admitted students and their parents also attended these events. In addition, a club-sponsored reception was held at the University of Chicago Faculty Club for the men's and women's varsity basketball teams, who were participating in a tournament there during the Thanksgiving holiday.

#### Alumni Fund

The Alumni Fund, led for the second year by Fund Board Chairman Peter M. Saint Germain, Class of 1948, continued its tradition of record-breaking performance. With totals of \$11,178,000 from 27,742 contributors, Fund Year 1986 marks the twelfth consecutive year of dollar increases, and the seventh year in eight of new million-dollar plateaus, as well as a new record for alumni participation. Alumni support of the Institute has never been stronger than in this, the 45th anniversary year of the Alumni Fund.

Two factors contributed to this success. Participation in the Alumni Fund continues to be broad-based, with 50% of the undergraduate alumni making a gift, and 31% of the graduate alumni. Equally important is gift upgrading, and, in this respect as well, 1986 was a banner year. Some 9,400 alumni, or 34% of the contributors, gave \$100 or more. The results at the higher giving levels were equally encouraging. A record 3,682 alumni, or 13% of the contributors, gave at least \$250. with 988 alumni, representing 3.6% of the contributors, giving \$1,000 or more. Given the new long-term objectives of the Alumni Fund--a \$20,000,000 annual fund and a median gift of \$100--such performance is a welcome sign.

Fund solicitation programs, including Direct Mail, Major Reunion Gift, Matching Gift, Senior Gift/Pledge, Telethon, and Young Alumni, were carried out as they have been in the past. The Graduate Alumni program, focusing on fund-raising by department, was on hold for the first three-quarters of the year, pending the appointment of a new Director which took place in April. It is expected that any lost ground will be quickly regained in Fund Year 1987.

Regional solicitation programs were conducted around the country, throughout the Fund Year. The keystone of the regional effort was the Personal Solicitation Program, held this year in Boston, New York, Detroit, Dallas, and San Francisco. All in all, 65 volunteers personally solicited 184 alumni, 93% of whom made a gift or pledge to the Alumni Fund. Of these, 54% increased their gift or pledge amount relative to Fund Year 1985, proving once again the effectiveness of face-to-face solicitation. Fall telethons were held in seven cities, and the Spring Geographic Telethons involved volunteers in 10 cities.

The Telethon Program continued to function as the primary means of personally soliciting large numbers of alumni, seeking new donors to the Fund and upgraded gifts from our regular givers. Some 929 alumni and student volunteer callers worked on behalf of the Fund, contacting 14,150 alumni, 73% of whom made pledges. A record total of \$710,000 was raised during telethons held throughout the course of the year.

The Young Alumni Program continued its work of developing the sense of commitment to MIT within our young classes, and its progress in this area is attested to by the 721 first-time gifts from the five youngest classes. The Associate Agents program, with 70 volunteer solicitors, brought in 280 gifts totalling more than \$6,000. The Class of 1981, making their 5th Reunion Gift to MIT raised \$29,409, 33% of which has been designated for the Class of 1981 Student Aid Fund. All told, 51% of the class made gifts in Fund Year 1986, and 71% have given at least once since graduation. Along similar lines, the Class of 1976, for their 10th Reunion Gift to MIT, raised \$36,206, 52% of which has been designated for the Class of 1976 Student Aid Fund. Over 53% of the class made gifts in Fund Year 1986, and nearly 78% have given at least once since graduation. These reunion gift campaigns were one year in duration.

In addition, the graduating Class of 1986 announced their two-part Senior Class Gift to MIT: A Bill Parker (Class of 1974) Plasma Light Sculpture, and the establishment of the Class of 1986 Student Aid Fund. Class members contributed over \$3,800 toward the gift--which was generously matched by the 50th Reunion Class of 1936--and pledged almost \$16,000 to be paid over the next four years, \$13,000 of which has been designated for the Student Aid Fund.

The Major Reunion Gift Program enjoyed great success with the 25th, 40th, and 50th Reunion Classes each announcing outstanding totals at Technology Day. The Class of 1961 raised \$2,174,094, setting new records for dollars raised and percent participation at a 25th Reunion. Almost a half-million dollars have been designated for the class project, a permanent endowment for Student Financial Aid. The Class of 1946 raised \$1,355,656, with over a half-million dollars designated for the class scholarship fund. The Class of 1936 raised \$3,531,117, and announced an additional \$2,178,000 in intended future gifts to MIT. These campaigns include all gifts and pledges made in the five years prior to the reunion; pledges are payable over the five years following the reunion.

Also worthy of comment are gift totals announced by the 60th and 65th Reunion Classes, both of whom ran one-year campaigns. The Class of 1926 raised a total of \$2,004,347, and the Class of 1921, \$3,205,070, demonstrating that support for MIT runs strong among our most senior alumni.

Of special note this year was the work done by an AdHoc Alumni Capital Campaign Committee, established jointly by the President of the Alumni Association and the Chairman of the Alumni Fund Board. The committee, composed of senior alumni leaders, was chaired by Harris Weinstein, Class of 1956. It pursued a number of questions and examined several issues including: MIT's public image; admissions policies, especially those with regard to relatives of alumni; and market research with respect to the alumni body. With regard to the Alumni Fund, the AdHoc Alumni Committee suggested two major goals to be achieved by the early 1990's, namely, to double the size of the Alumni Fund to \$20 million annually, and to double the median gift to the Fund from \$50 to \$100.

Finally, the Alumni Fund staff was augmented by the appointment of Jean Blodgett Bruns to the position of Associate Director of the Fund, and Nancy M. Hack to the position of Director of Graduate Alumni Programs. The current and future success of the Alumni Fund is founded and depends upon the tireless work of thousands of volunteers, backed by a dedicated and capable staff.

#### Technology Review

In a year when the commercial performance of popular magazines of science and technology faltered, TECHNOLOGY REVIEW is able to report marketplace performance exceeding that of 1984-95 by every measure. Net advertising income was slightly higher than the year before--but by a margin that compares favorably with that of other nontechnical magazines of science and technology, thanks chiefly to the efforts of Peter Gellatly, Business Manager, and the sales force of the Leadership Network. Meanwhile, circulation increased, and the REVIEW's costs to obtain new non-alumni subscribers decreased.

To the extent that editorial activities were responsible for these achievements, they should be credited to the process of revitalizing the staff that began with the appointment of Jonathan Schlefer as Managing Editor in the fall of 1985. Schlefer joined TECHNOLOGY REVIEW in 1982 as Senior Editor, and his contributions have been of growing importance ever since. Soon after Schlefer's appointment, Sandra Hackman--she joined the REVIEW in 1979 as copy editor and manager of the "Books and Comment" section--was named Senior Editor to replace Schlefer; and shortly thereafter Marc S. Miller, Class of 1969, formerly Managing Editor of Southern Exposure magazine, joined the staff as Senior Editor, replacing Tom Burroughs who now has a similar assignment at the Smithsonian's new magazine, Air and Space. Finally, to further strengthen the editorial staff, Laura van Dam came from New England Business to be Associate Editor, and Beth Horning, a free-lance writer of poetry, essays, and fiction, joined the REVIEW to be part-time Associate Editor.

With these personnel changes in place, the REVIEW gained strength in its recent issues, better fulfilling its stated editorial purpose: to report on new developments in technology and--especially--their policy implications. Notable among articles this year were an evaluation of the issues of critical materials by Professor Joel P. Clark, Sc.D., Class of 1972 of MIT; a report by Louis Lavoie of Honeywell on "The Limits of Soviet Technology"; "Construction's High-Technology Revolution" by Professor Fred Moavenzadeh of MIT; a widely-admired article on radon pollution by Professor Anthony Nero of the University of California's Lawrence Berkeley Laboratory; a review of the technology and politics involved in verifying compliance with arms-control treaties by Michael Krepon of the Carnegie Endowment for International Peace; and a comparative study of computer research and development--and those who do it--in Japan and the U.S. by Professors D. Eleanor Westney of MIT and Kiyonori Sakakibara of Hitotsubashi University, Tokyo. By far the most controversial article of the year was "Why Computers May Never Think Like People," a pre-publication excerpt from a book by Professors Hubert and Stuart Dreyfus of the University of California at Berkeley.

Having resolved a year ago to bring more of the personality of important engineers and policymakers into the pages of the REVIEW, its staff brought two such features into the 1985-86 issues: an article-length profile of Professor Matthew Meselson of Harvard University by Alison Bass, Senior Editor; and an interview with Richard DeLauer, Undersecretary of Defense for Research and Development during President Reagon's first term, by Jonathan Schlefer and Sandra Hackman. An interview by Alison Bass with Professor David Baltimore, Director of the Whitehead Institute for Biomedical Research, will appear in the October, 1986, issue.

Professor Moavenzadeh's article in the October, 1985, issue was honored by the National Society of Professional Engineers: first place in the general-interest magazine category in its 1986 Journalism Awards Program. Runners-up were articles in Discover and Science Digest.

There were honors, too, for TECHNOLOGY REVIEW's design and illustration: eight covers, layouts, and illustrations from 1985-86 issues were included in the 1986 exhibition of the Art Directors Club of Boston. With Nancy Cahners, Design Director, on maternity leave for the second half of the 1985-86 year, the responsibility for design as well as production fell to Kathleen Sayre, Design/Production Manager, who discharged both assignments with distinction. Elizabeth Fullon, formerly Assistant to the Editors, became Assistant Production Manager during the year and was a major factor in the improving appearance of the REVIEW's pages devoted to alumni and MIT activities. Fullon was succeeded by Lori Nollet, who in turn undertook work in production during much of Cahners' leave.



A major effort during the second half of the year was devoted to planning how TECHNOLOGY REVIEW should best support the major capital campaign being planned by the Institute to begin in 1988. The conclusion is that the REVIEW will retain its traditional role as a cultivator--rather than a solicitor--of contributions, and that it will intensify its efforts to report developments at MIT and alumni activities nationwide under the direction of Susan Lewis, Senior Editor, and Sandra Knight, Senior Editor in charge of Class News.

In these deliberations, as well as in reviewing its performance more generally, the REVIEW was supported throughout the year by its Advisory Board under the chairmanship of Edward T. Thompson, Class of 1949. Thompson in particular was generous of his time and effort in the magazine's behalf. The REVIEW was honored by the acceptance of membership on the Board by Professors Robert W. Mann, Class of 1950, and A. Rae Goodell. But it suffered a serious loss in the death of a long-time member, Professor David J. Rose PhD, Class of 1950, whose commitment to a holistic view of technology and society made him a sympathetic, interested, and valued counsel.

Through July, 1986, average alumni circulation of the REVIEW was 39,539; this compares with 37,907 for the previous year, and reflects the increasing participation in the 1986 Alumni Fund. Direct-mail sales of the magazine to non-alumni were more successful and less costly in 1986 than in the previous year, thanks chiefly to the successful use of new sales materials and strategies by Julie Zuckman, Circulation Manager. More would-be subscribers accepted trial subscriptions, and more of them--by fully 15 percent--became paid subscribers. The REVIEW's commercial success is the more remarkable in view of the tardiness--by several weeks behind specified publication dates--of several issues, the result of the changes in editorial personnel. Those changes having now been accomplished without jeopardy to the quality of the magazine, the REVIEW seems poised for a highly successful year in 1986-87.

#### Alumni Information Management

Planning for the impending campaign for MIT has had significant impact on the organization and work of the Alumni Information Management Unit during FY86. Two new positions were filled with the appointment of Bruce A. Mogayzel in August as Associate Director, Alumni Information Management and the appointment of Katherine R. Cochrane in November as Administrative Officer of the Alumni Association. With these organizational changes complete the Director focused on planning and project management for the information system requirements for the Campaign.

Several groups were formed with representatives from the Alumni Association, Treasurer's Office, Resource Development, School of Engineering Development Office and Administrative Systems. These groups worked simultaneously on various stages of the planning and implementation of information resources for the Campaign.

Major milestones were the acceptance in early May of the recommendations of the Campaign Information Resources Group for overall information systems requirements for the Campaign; the acceptance of the functional specifications for a Volunteer Control system, the creation of a new file on the database, the assignment of two programmers to the Volunteer Control project; and the completion of functional specifications for a Prospect Tracking system. Target dates have been established for the completion of Volunteer Control by September, and the completion of Prospect Tracking and Management Reports by the end of calendar 1986.

In addition to involvement in the Campaign planning, work continued on modifications to the Reunion Gift system; the transfer of output programs to the NATURAL Security environment; the addition of the Special Constituencies and Student Activity files to the database; and the replacement of the terminal network in the Information Management offices in Building 12. The volume of entry to and production output from the database continues to grow, as does the size of the database itself which now contains 111,963 records, 90,709 alumni and 21,254 records for all other donors to the Institute.

Other personnel changes during the year involved the addition of two programmers in mid-February when Susan L. Giordano joined the staff and Candace K. Hopkins moved to a programming position. The position of Manager of Production Output was left vacant for the remainder of the year. In June Barbara A. Durland was appointed to a new position as Assistant to the Vice President and Treasurer and Executive Vice President of the Alumni Association for Information Systems. Bruce A. Mogayzel was named interim Director of Alumni Information Management.

#### Administration

Reorganization was the watchword for the year 1985-86. Ms. Katherine Cochrane was appointed Administrative Officer of the Alumni Association. This change was the result of the decision by the Executive Vice President to reorganize functions carried out by the former Manager of Administrative Operations and the Director of Alumni Information Management into one position. Ms. Cochrane came from the Office of the Dean for Student Affairs and has worked at the Institute since 1973.

This year was spent organizing the unit into a team that will provide the Alumni Association with appropriate administrative support. The staff consists of Manager for Financial Operations, and administrative assistant, and a Senior secretary. Changes initiated but not yet concluded are the development of a new financial report that will tie together the unique accounting problems of the Alumni Association with the Institute

accounting system; a new approach to the problem of reconciling Technology Review's fulfillment house financial statements with the Institute financial statements; development of an orientation program for new Alumni employees; increased involvement in office automation issues, as well as training issues; filling nine staff positions and seven support staff positions.

The coming year will bring many more changes as we plan for the coming campaign and the move of Technology Review.

WILLIAM J. HECHT